

TOPEX/Poseidon Observation of the Global Ocean Dynamics

Lee-Lueng Fu

**Jet Propulsion Laboratory
California Institute of Technology**

Presentation Outline

- Mission Performance
- Global Mean Sea Level Change
- Basin-Scale Ocean Variability
 - Interannual
 - Annual
 - Intraseasonal
- Mesoscale Ocean Variability
- Ocean Data Assimilation
- Ocean Tides
- Internal Gravity Waves
- Conclusions and Outlook

Mission Performance

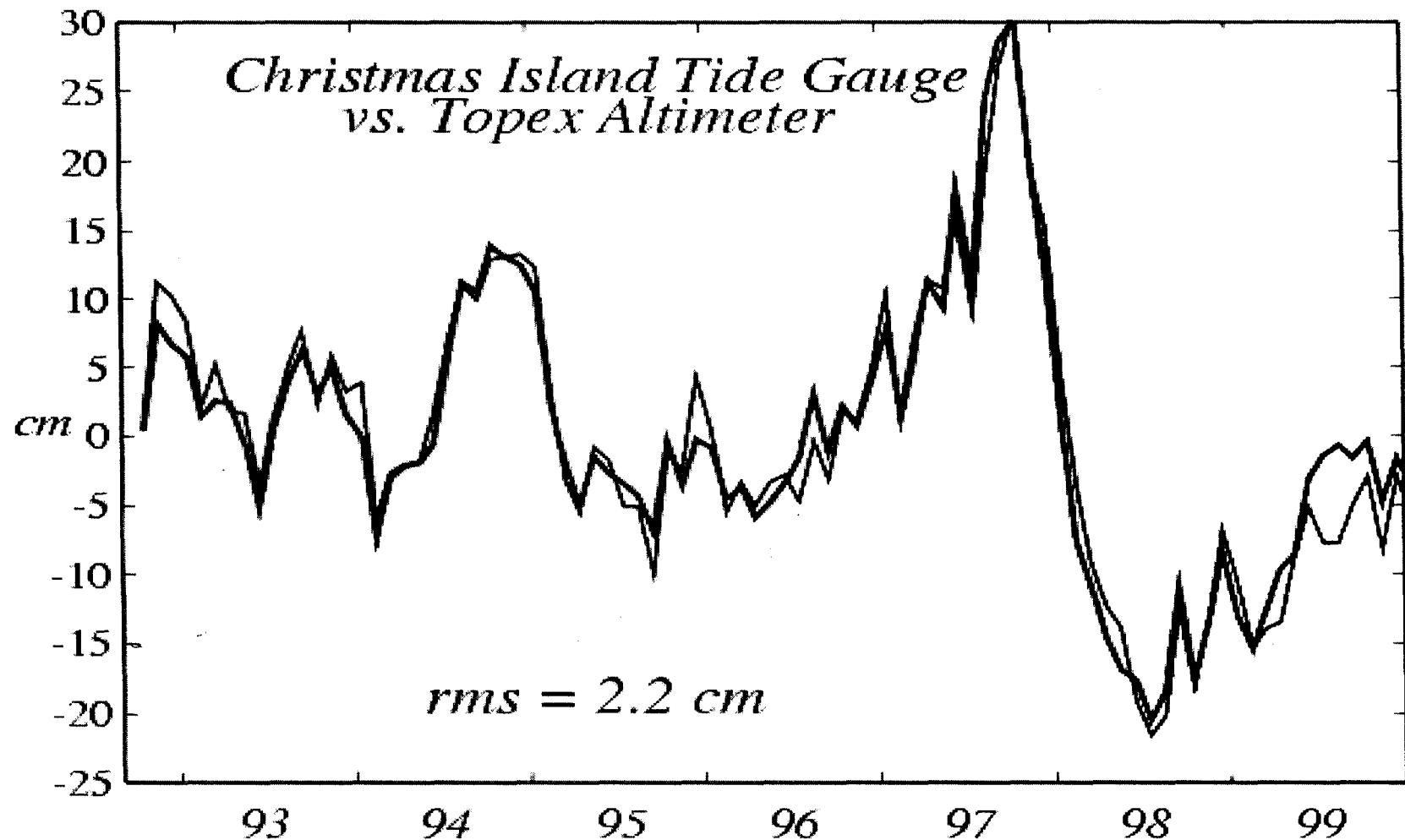
- **Longest continuous data record from a spaceborne radar measurement.**
- **Launched in August, 1992, this joint US/France mission has been measuring the global ocean topography with 99% data return rate.**
- **The rms accuracy at 1/sec data rate is 4.2 cm.**

TOPEX/POSEIDON Measurement Accuracy

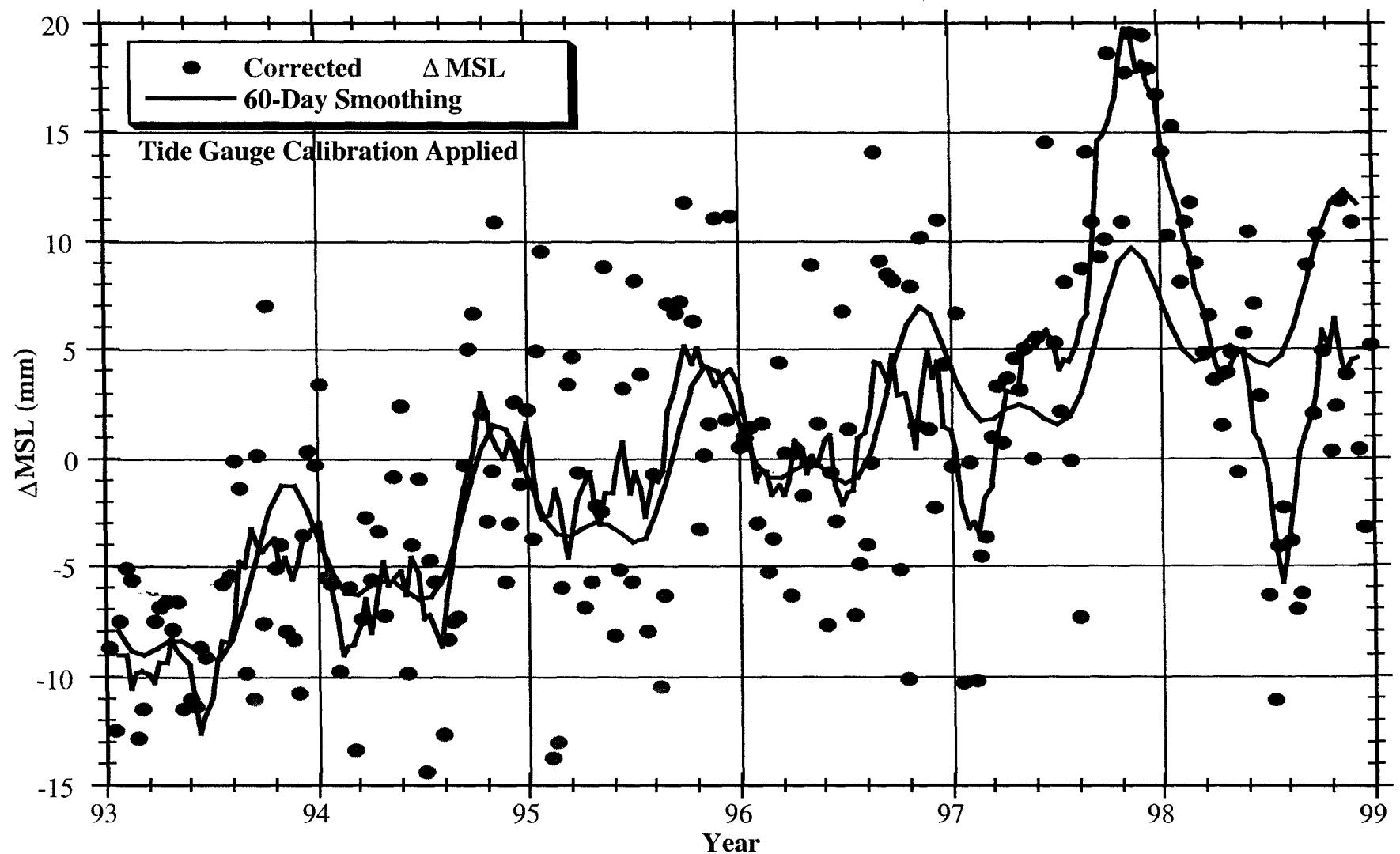
(one sigma values in cm)

	TOPEX	POSEIDON
<hr/>		
Altimeter		
Altimeter noise	1.7	2.0
EM bias	2.0	2.0
Skewness	1.2	1.2
Ionosphere	0.5	1.7
Dry troposphere	0.7	0.7
Wet troposphere	1.1	1.1
Total Altimeter Range	3.2	3.7
<hr/>		
Precision Orbit Determination		
Radial orbit height	2.0	2.0
Single-pass sea surface height	3.8	4.2

After spatial and temporal smoothing ($1^\circ \times 4^\circ \times$ monthly), the measurement errors are reduced to 2 cm.

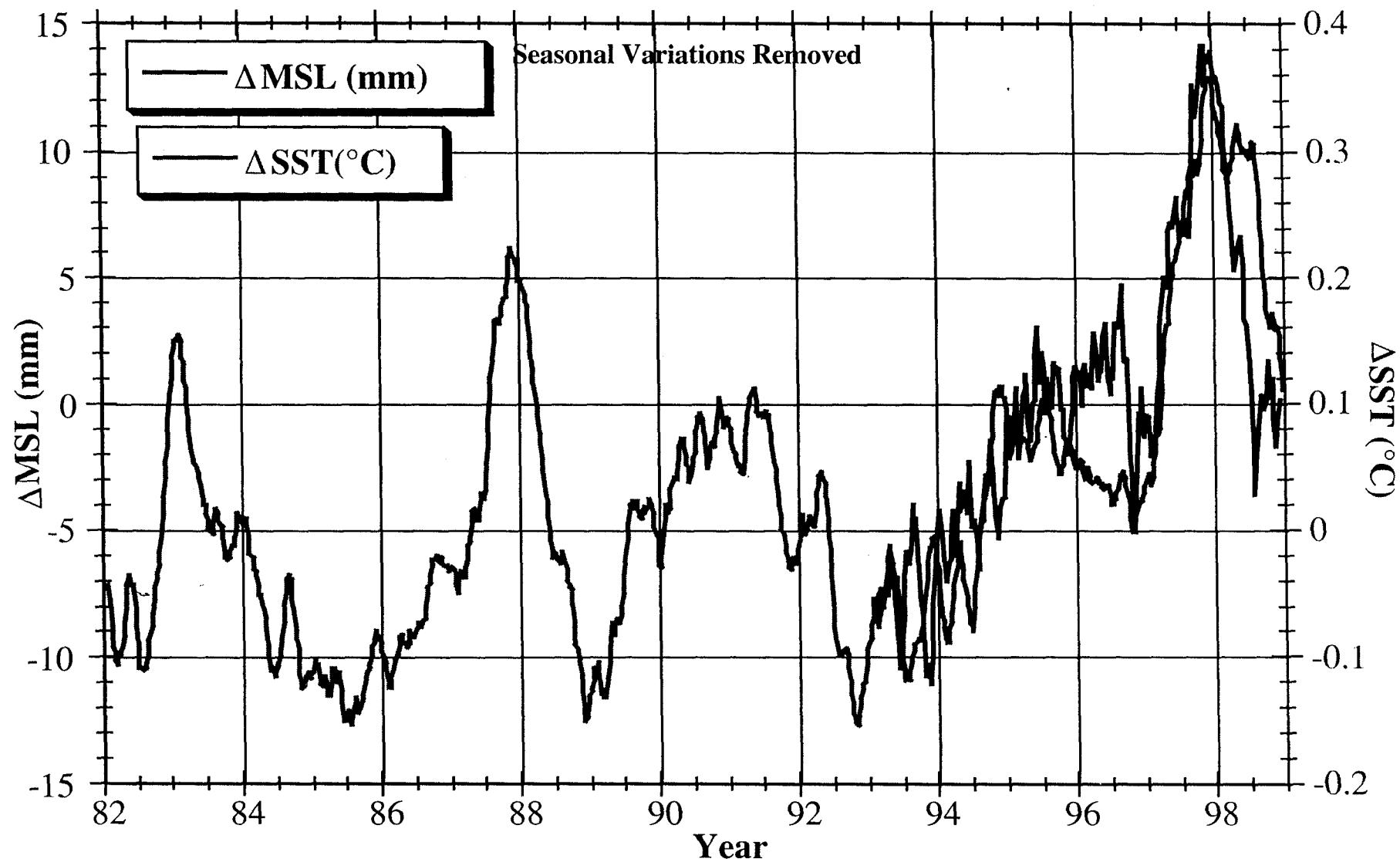


Global Mean Sea Level Change



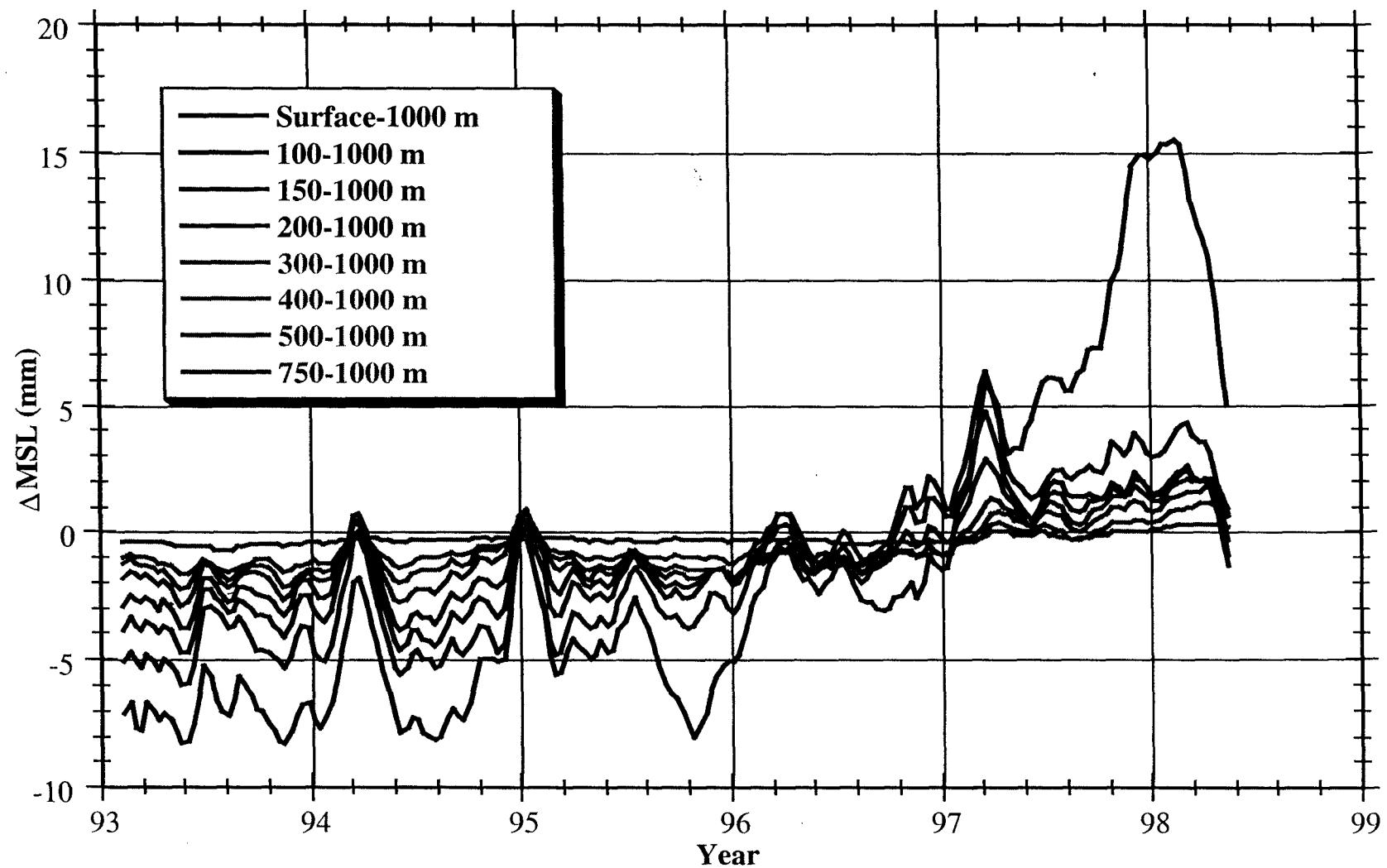
Nerem et al (2000)

Global Mean Sea Level and Sea Surface Temperature



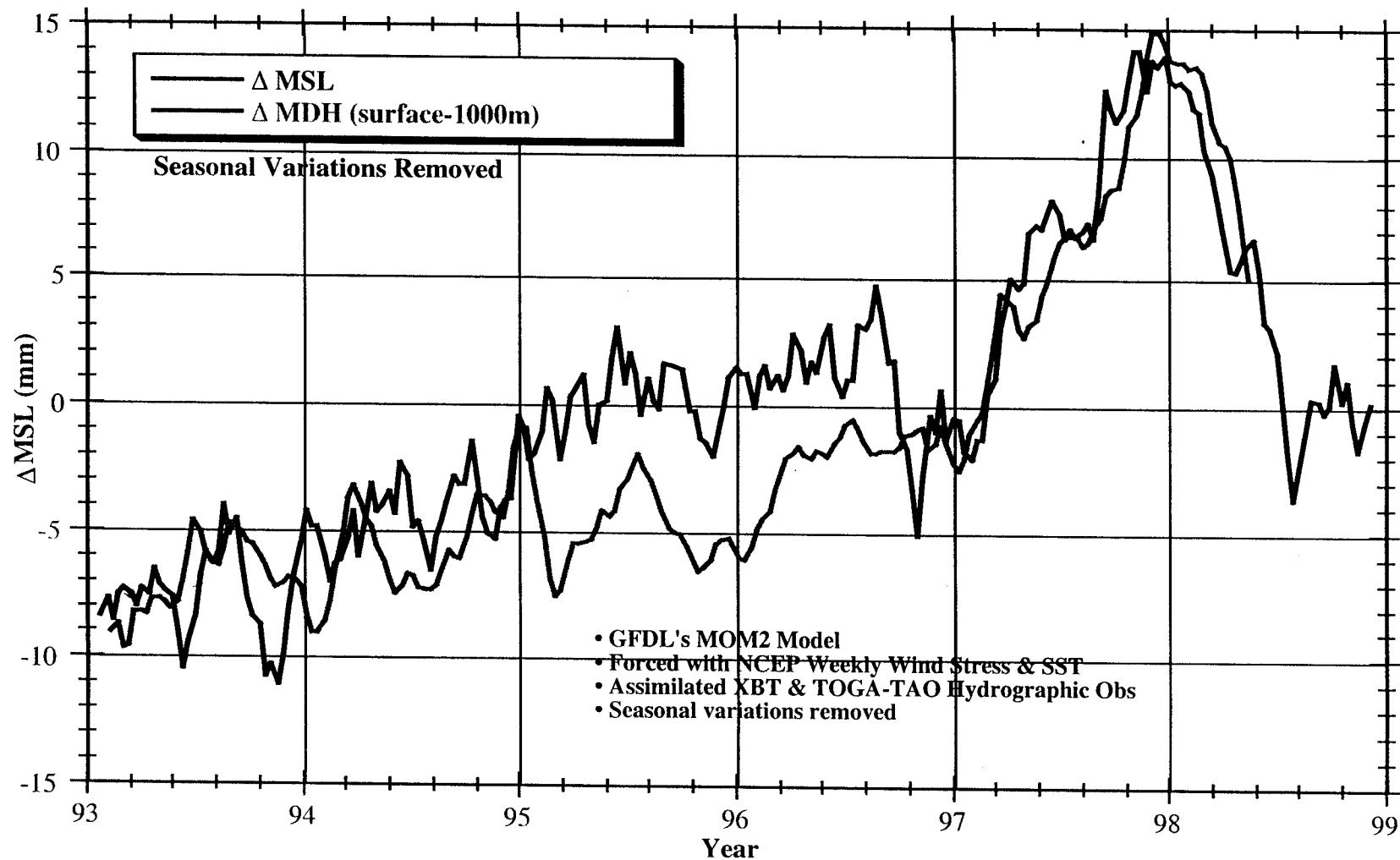
Nerem et al (2000)

Global Mean Dynamic Height From a Model

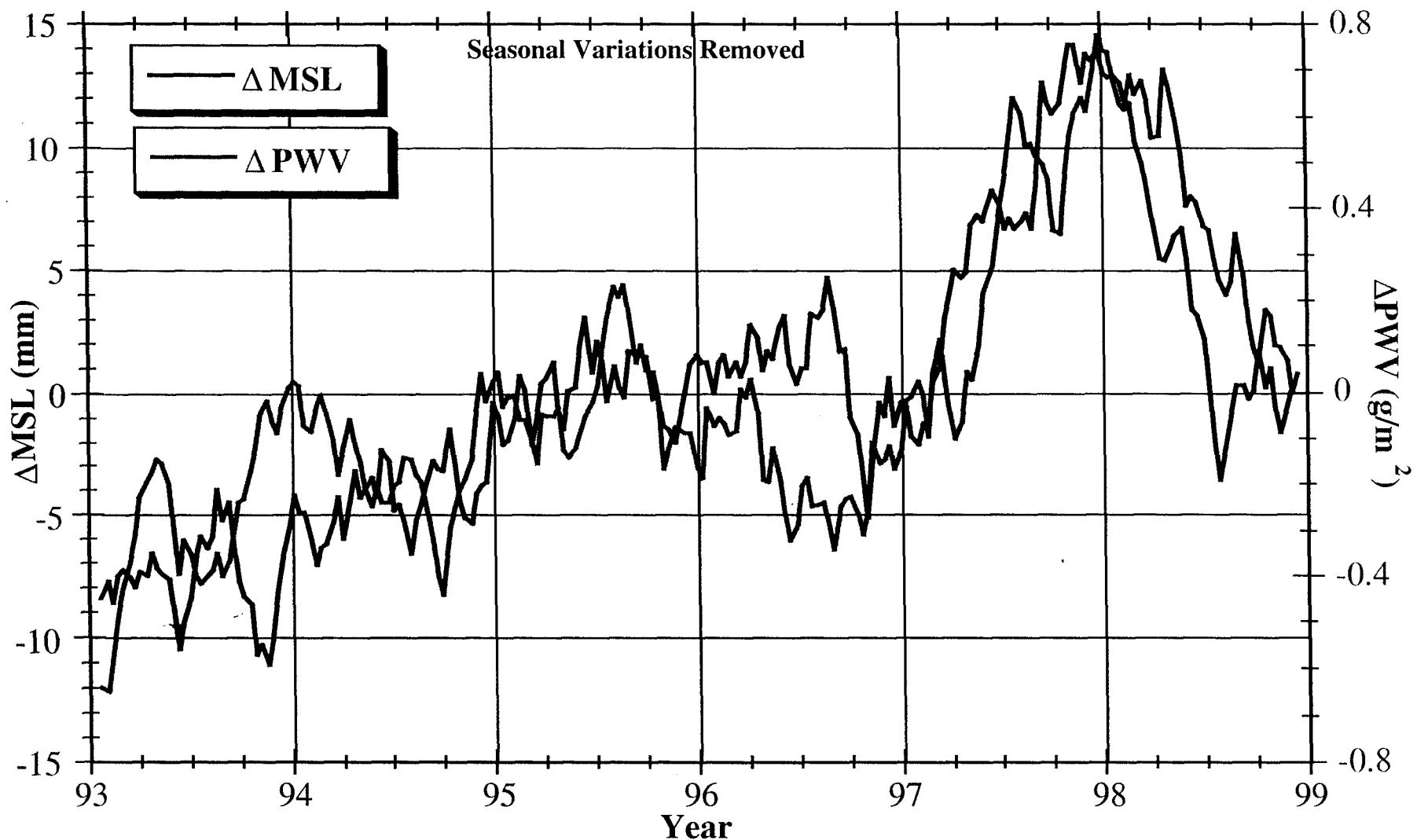


Nerem et al (2000)

Global Mean Dynamic Height From a Model



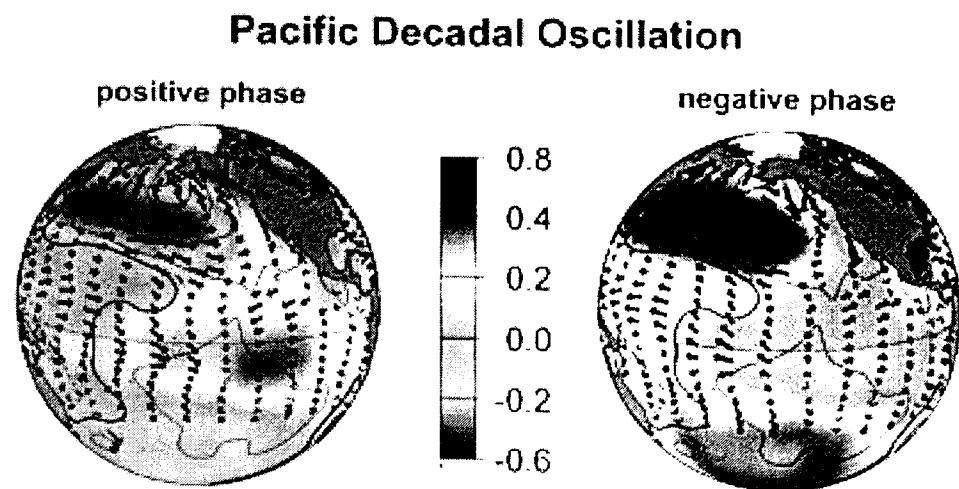
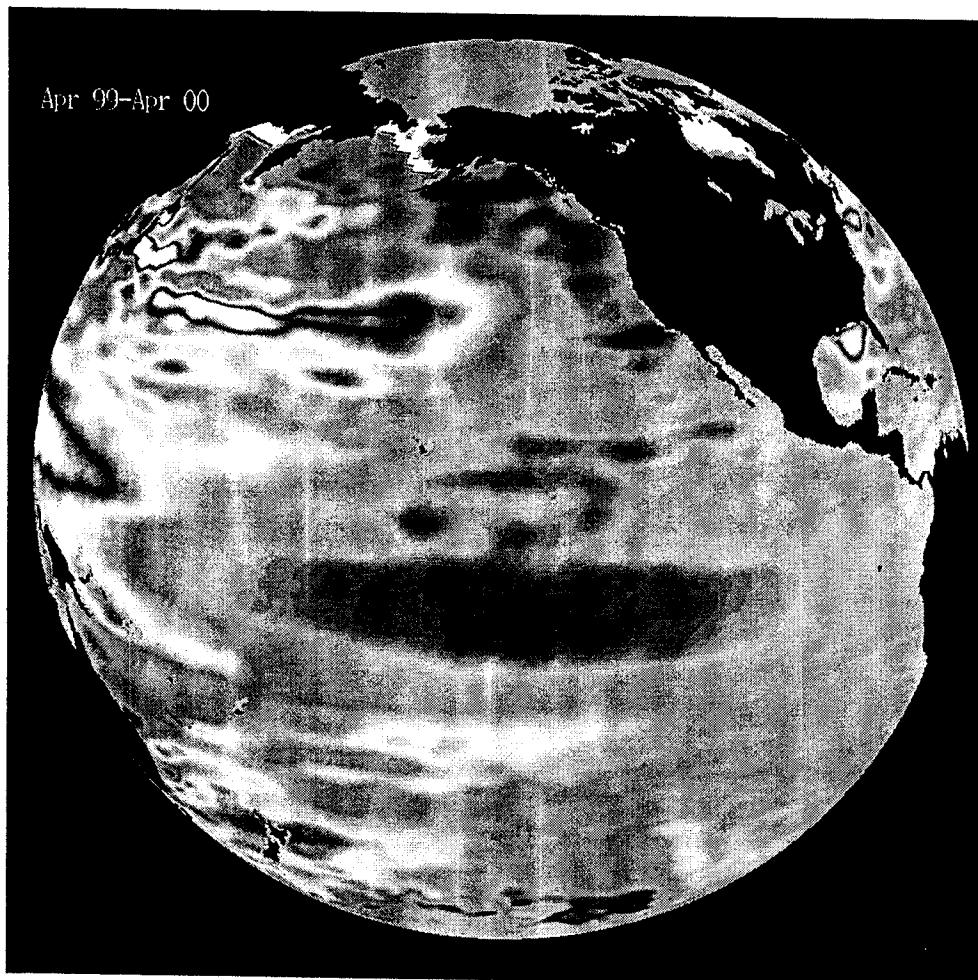
Global Mean Sea Level and Water Vapor



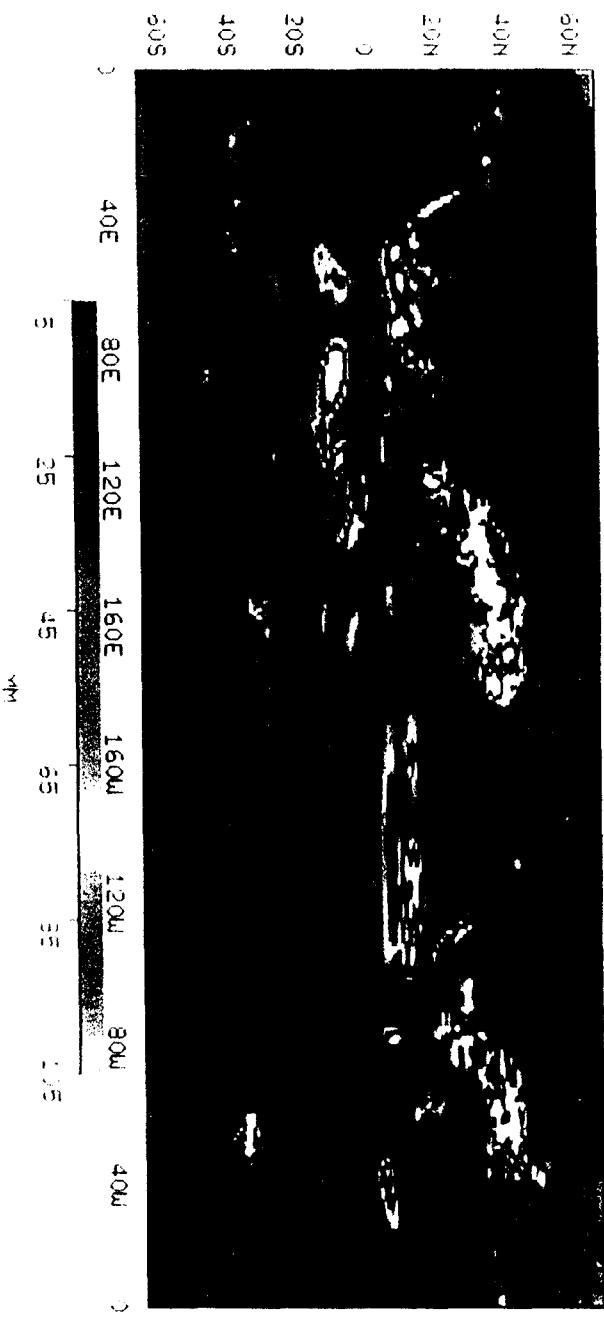
Nerem et al (2000)

Signs of Decadal Change?

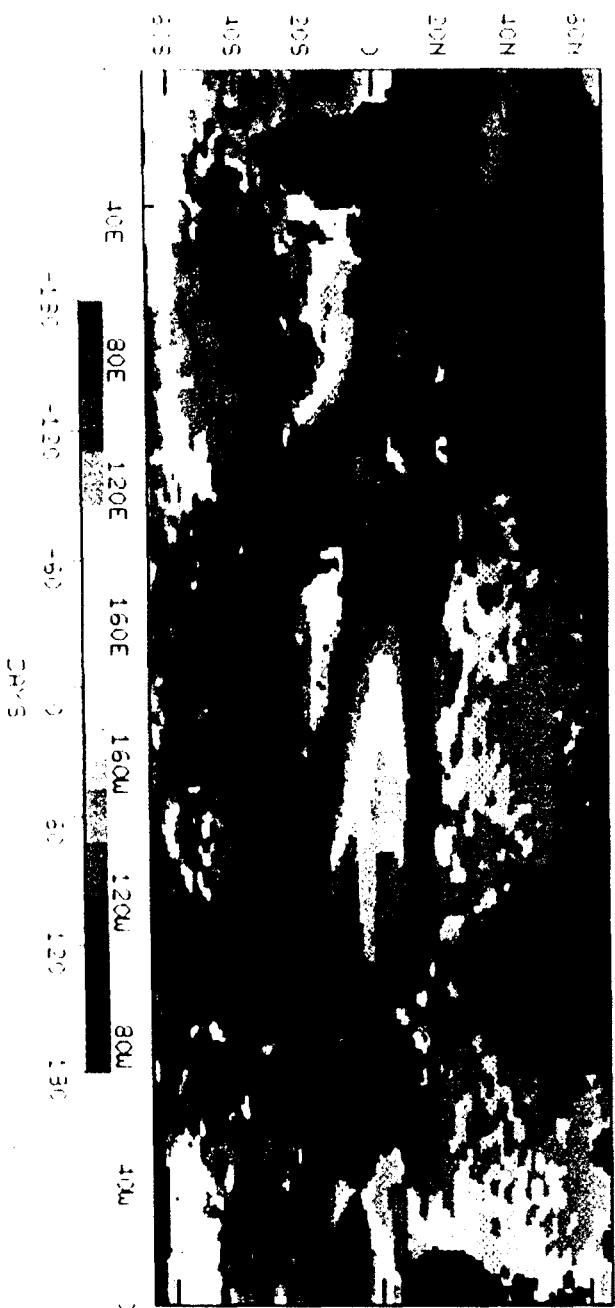
*TOPEX/Poseidon ocean
topography averaged from
April'99 to April'00*



TOPEX Position Amplitude of Annual Cycle 1993-1997



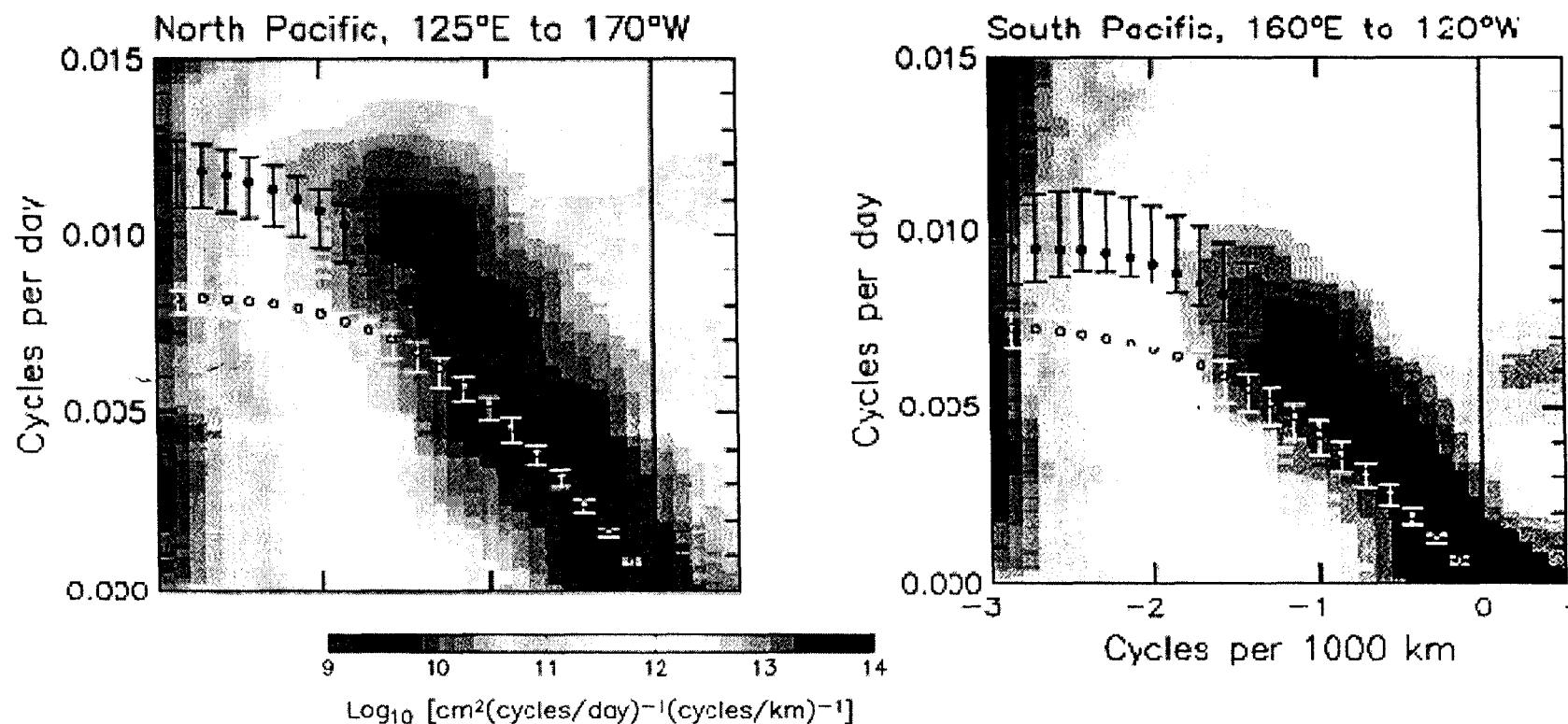
TOPEX Position Phase of Annual Cycle 1993-1997



TOPEX/Poseidon Results

Oceanic Rossby Waves

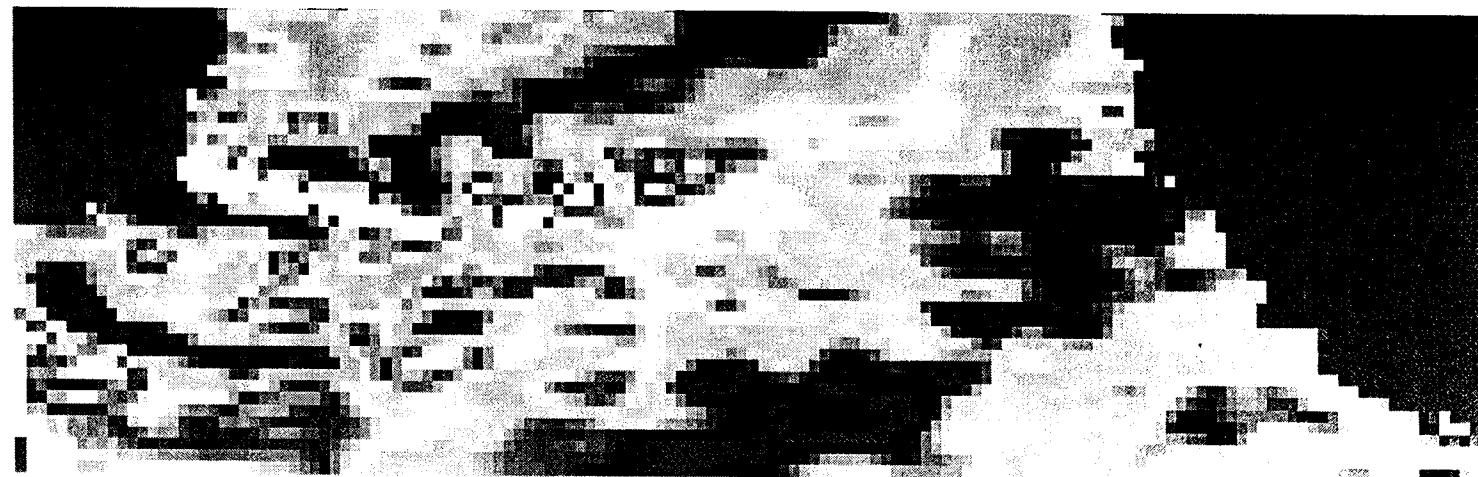
Sea surface height spectra (along 24° in the Pacific Ocean as shown below) have led to revision of the conventional theories for oceanic Rossby waves (circles) into a new one (solid dots) that fit the data better. (from Fu and Chelton, 2000)

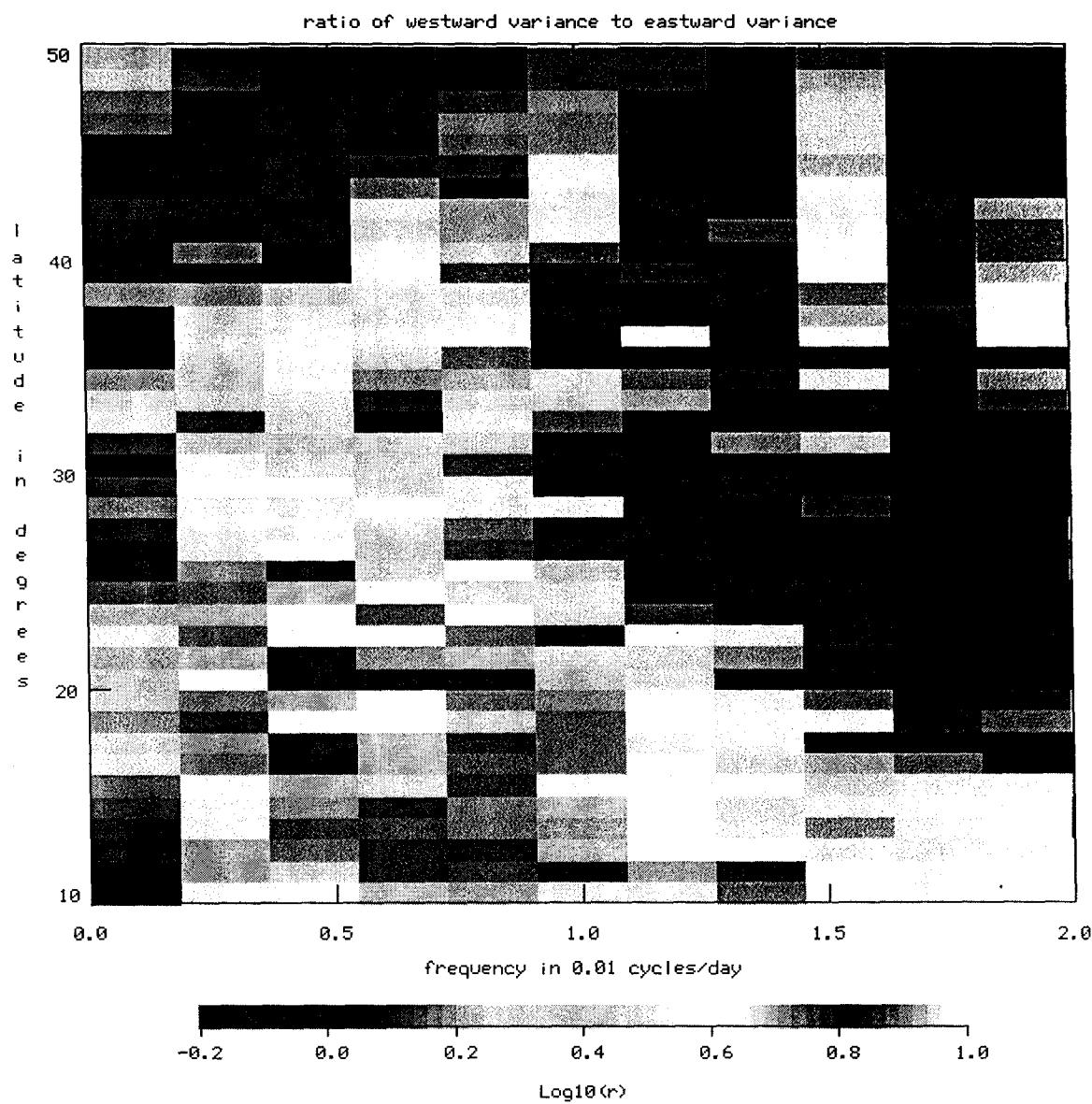


SSH Anomaly (June 1, 2000) 90-day average

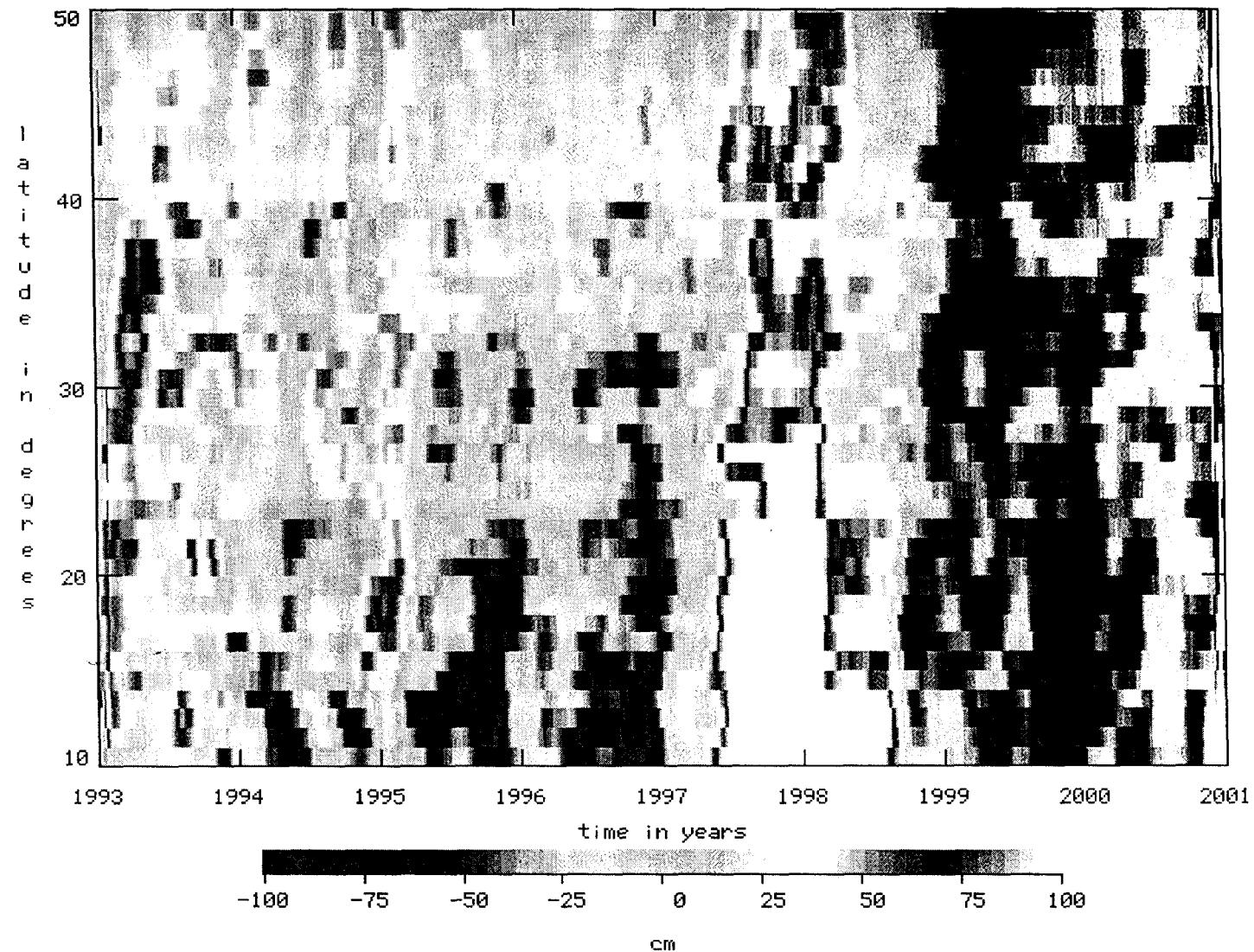


Westard Propagating Component





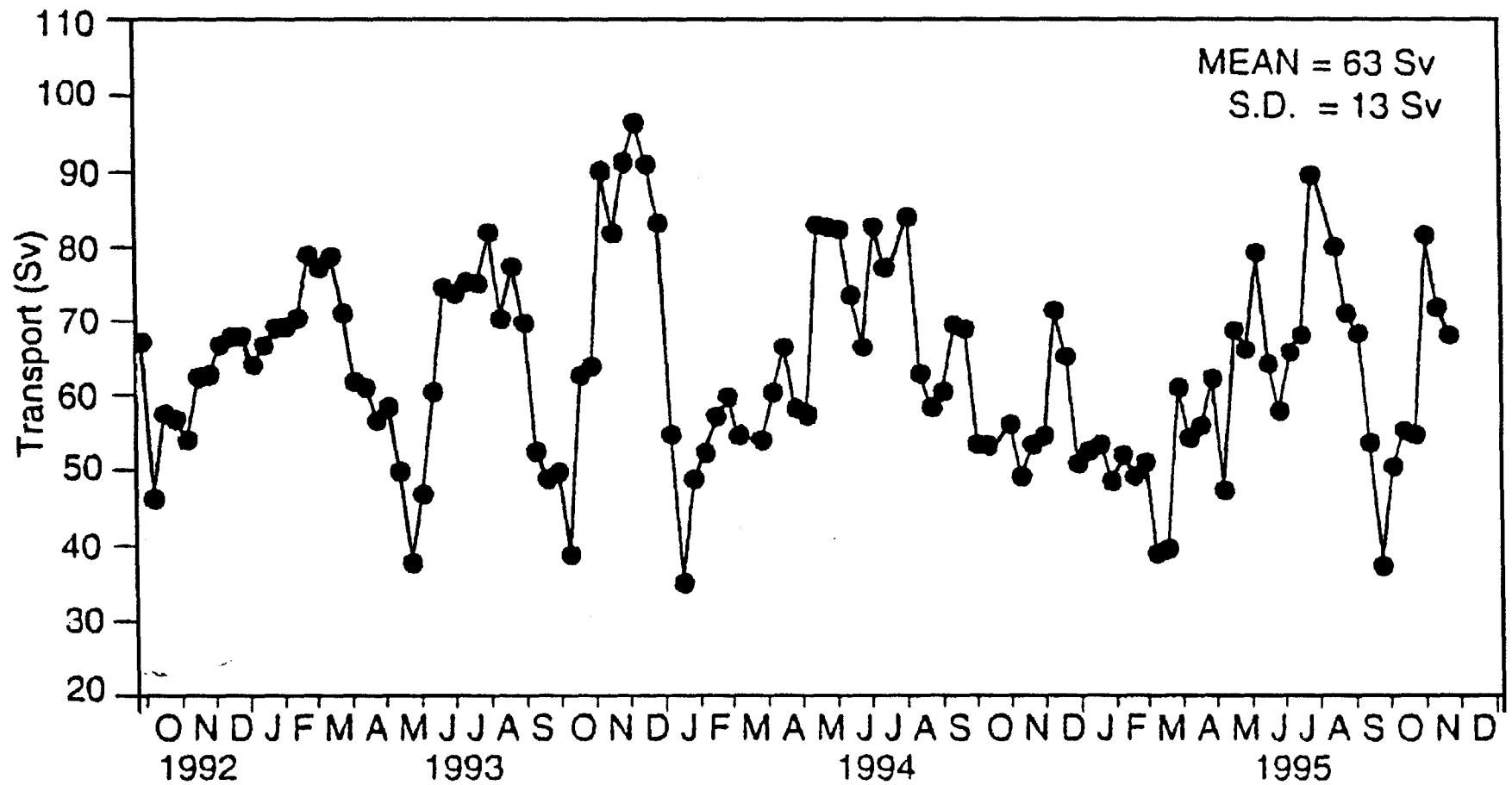
SSH anomalies (60-day average) along US west coast



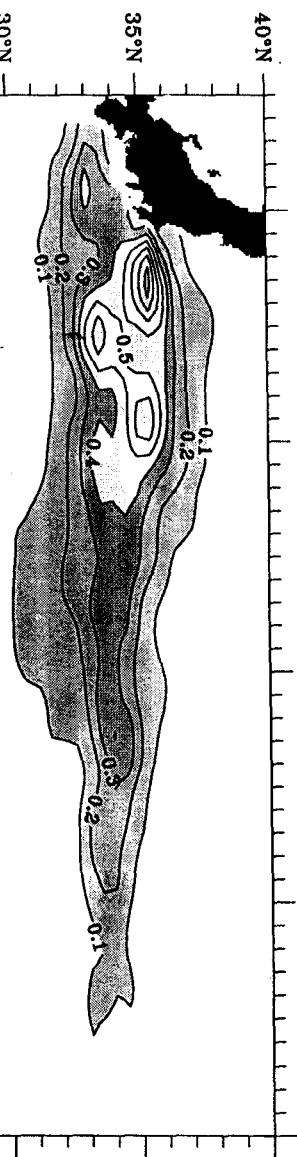
SSH Anomaly June 1,2000 90-day average



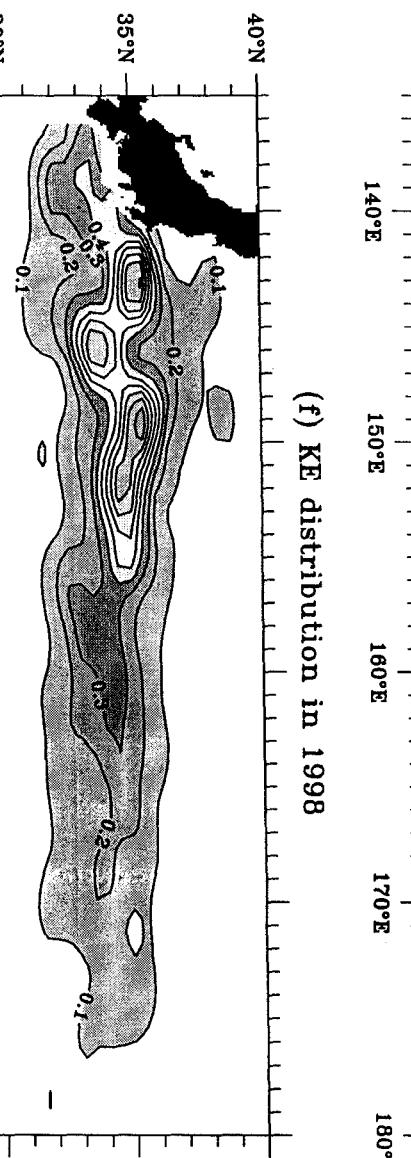
- Monitor the transport of Kuroshio



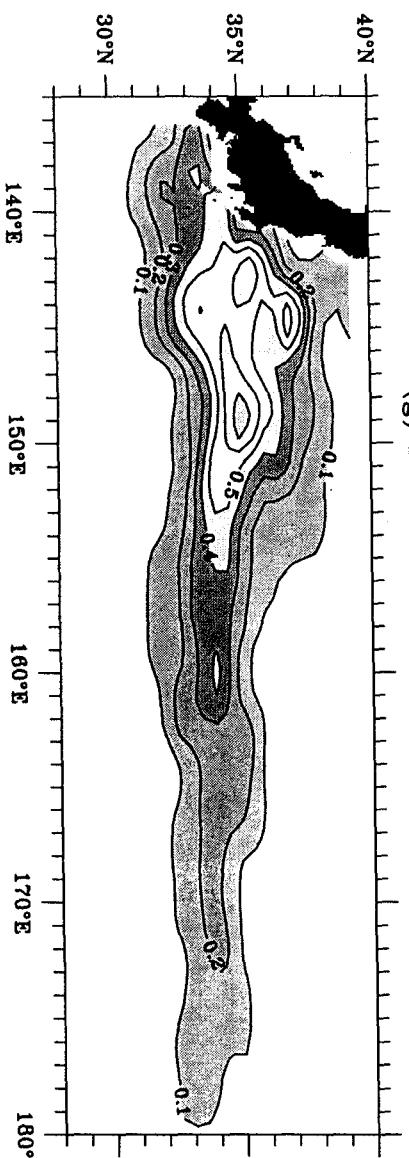
(e) KE distribution in 1997



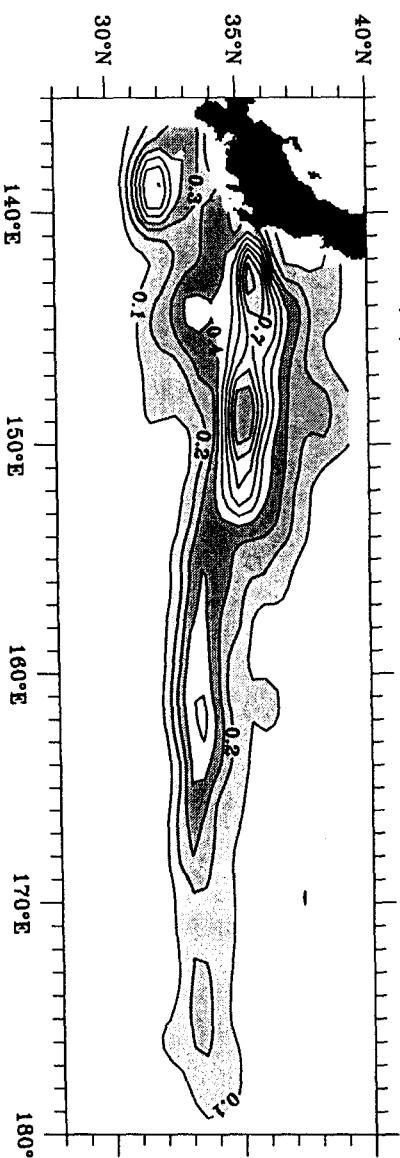
(f) KE distribution in 1998



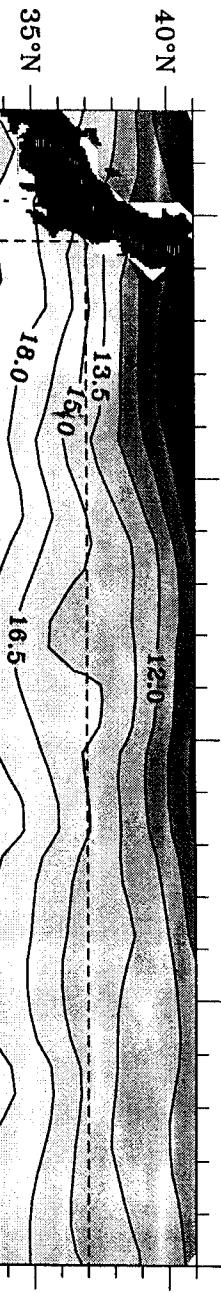
(g) KE distribution in 1999



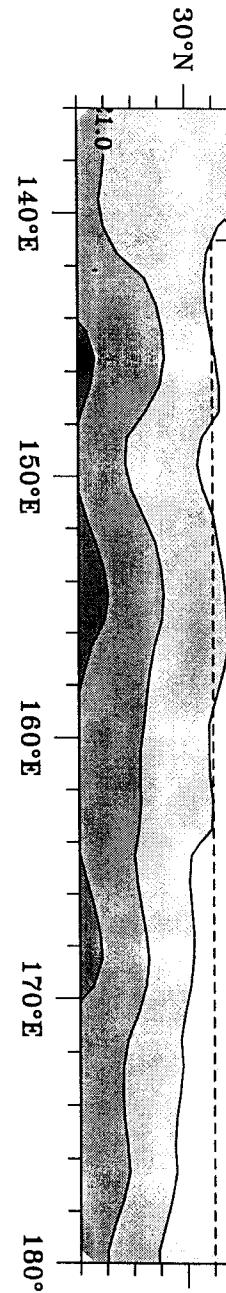
(h) KE distribution in 2000 (Jan–Nov)



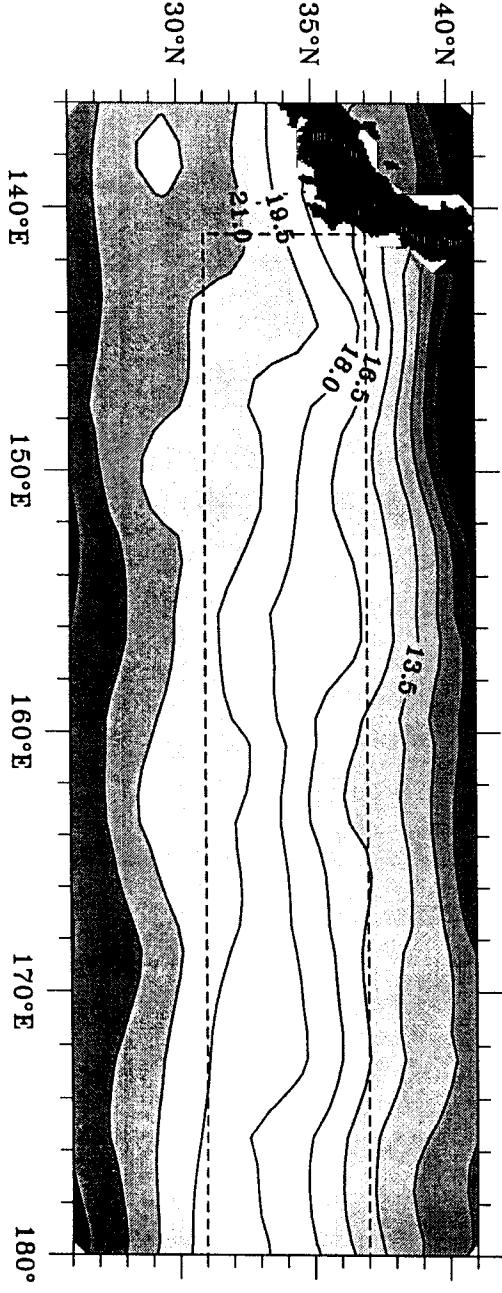
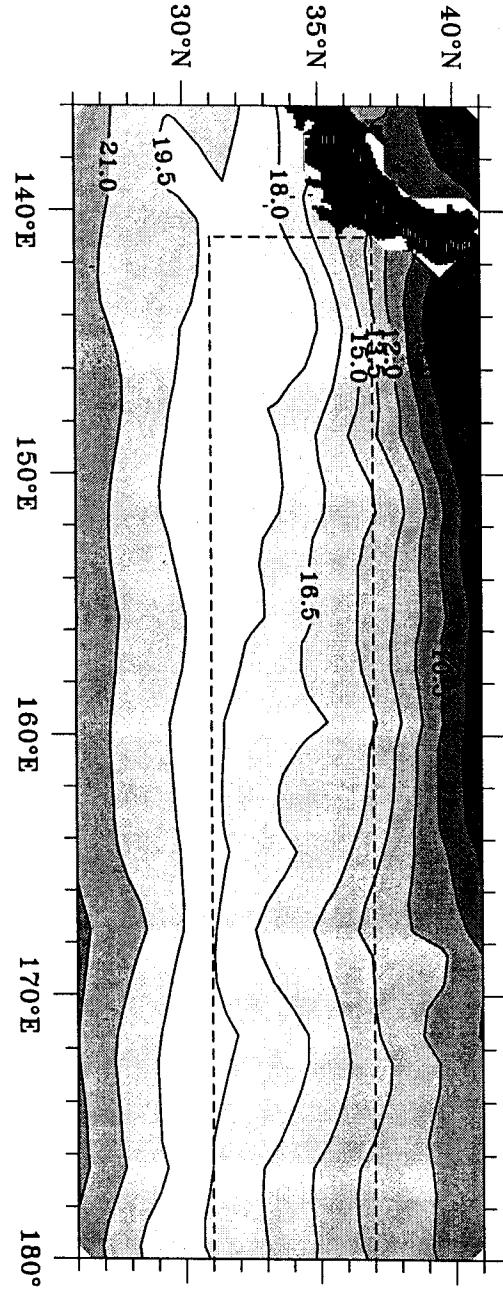
(a) SST: January 1993



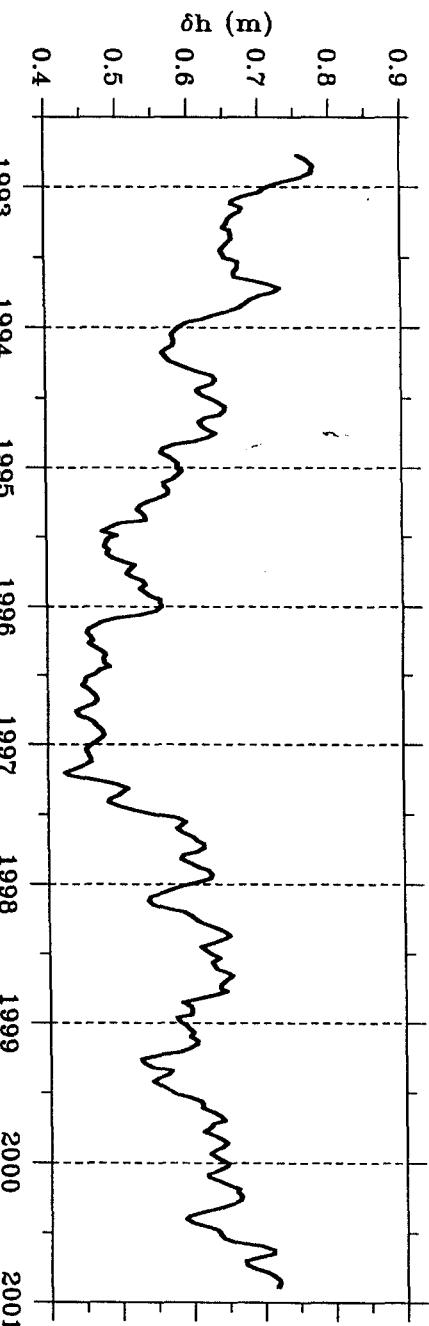
(b) SST: January 1996



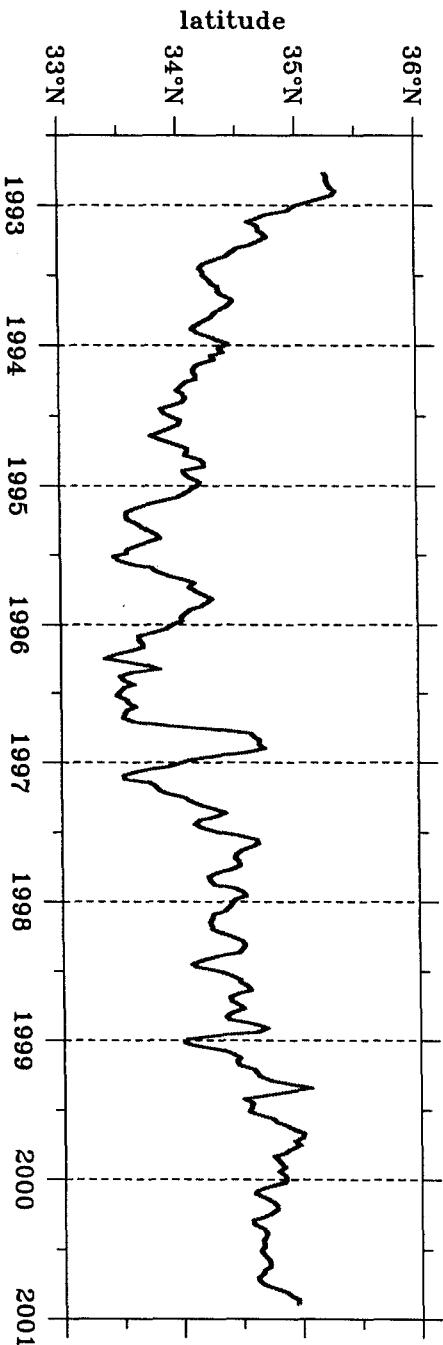
(c) SST: January 1999



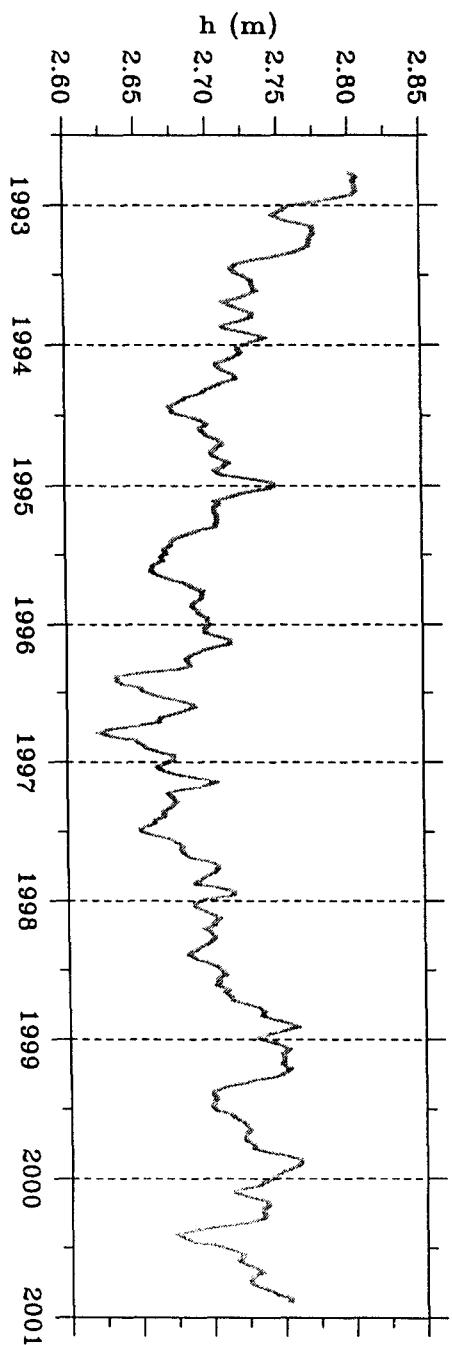
(a) Zonally averaged δh across KE (141°E - 180°)



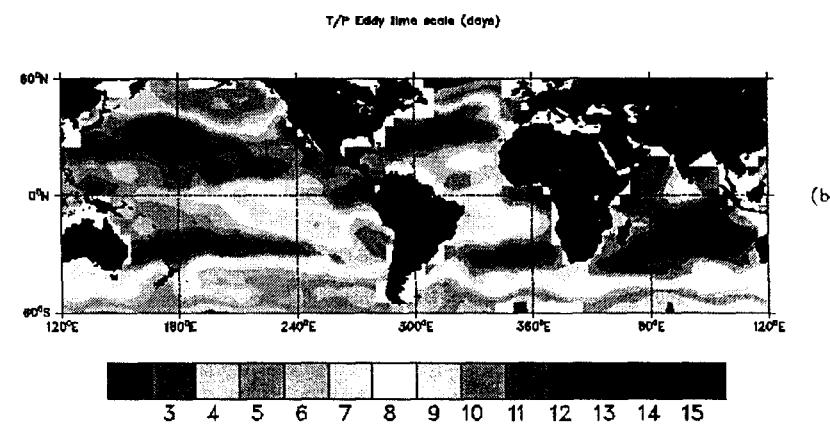
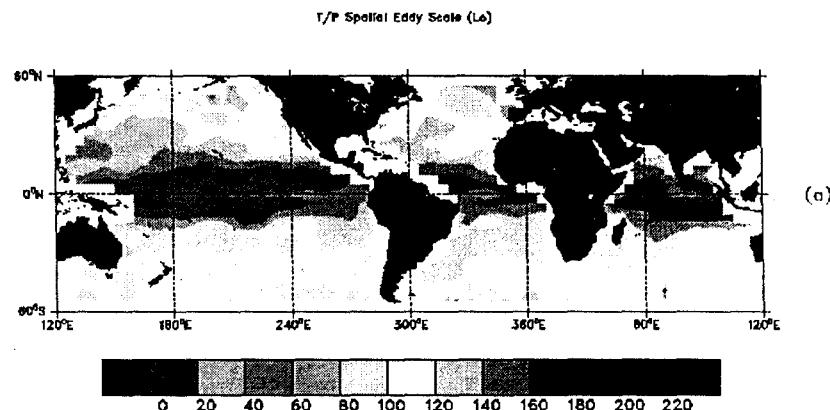
(b) Zonally averaged KE axis latitude (141°E - 180°)



(c) Zonally averaged SSH in the recirculation gyre



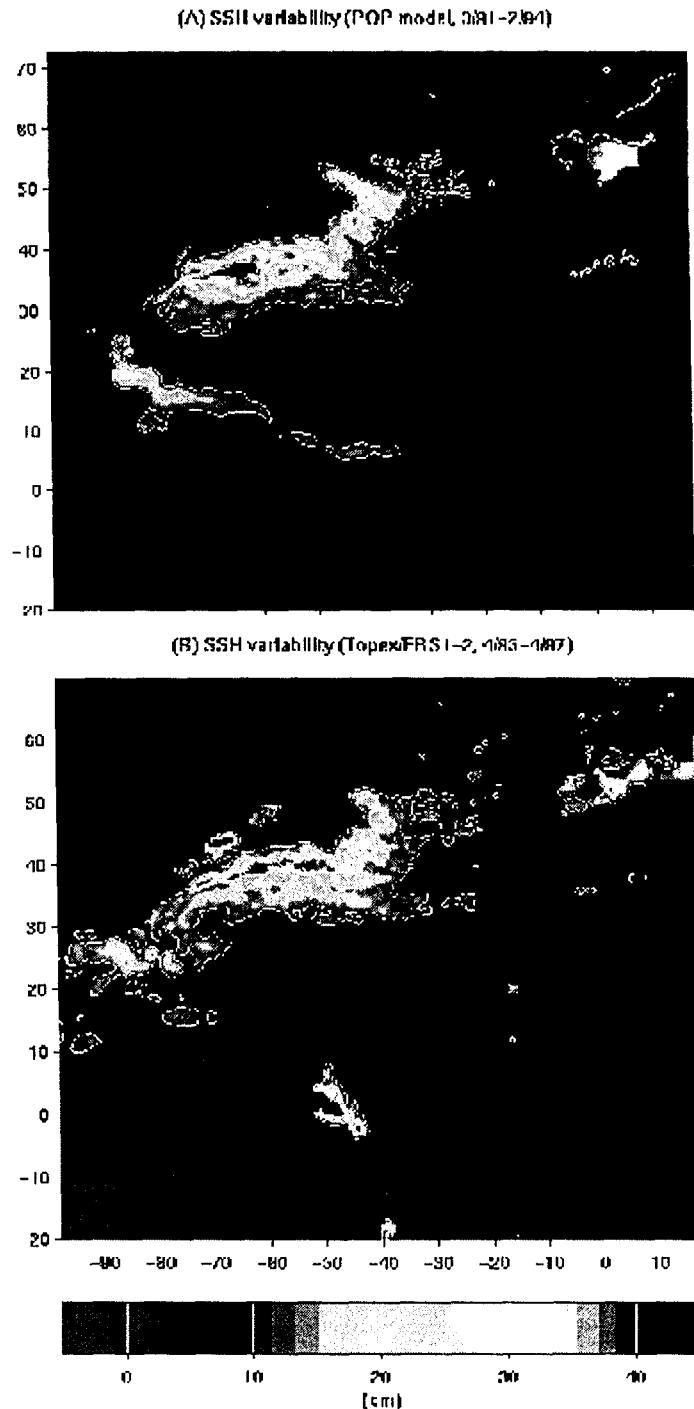
- Spatial and Temporal Scales of Mesoscale Eddies



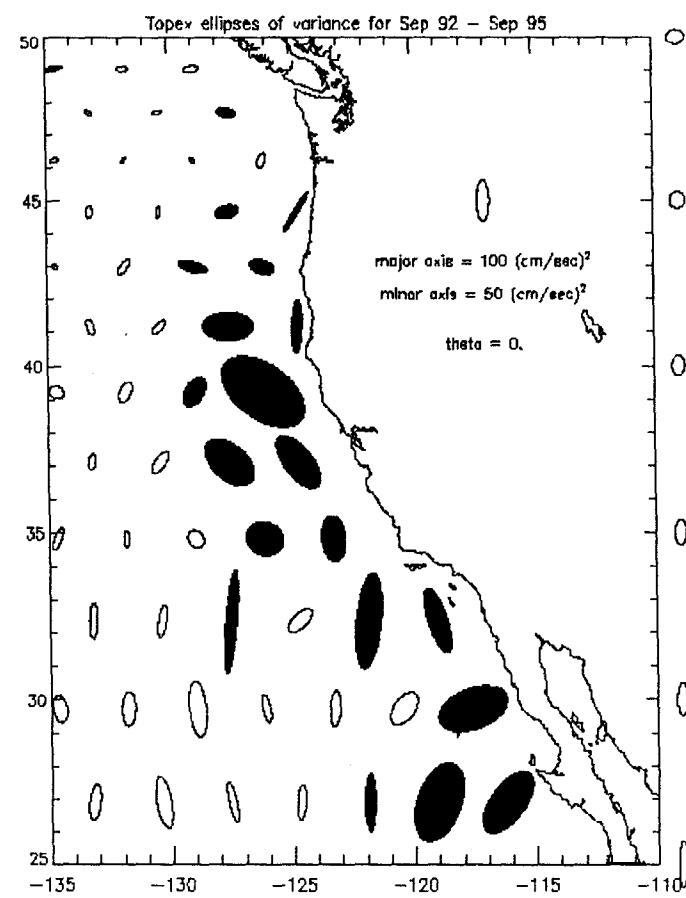
TOPEX/Poseidon Results

T/P data plus ERS1-2 data (upper) have provided test data base for the development of high-resolution ocean general circulation models down to 10-km resolution (lower).

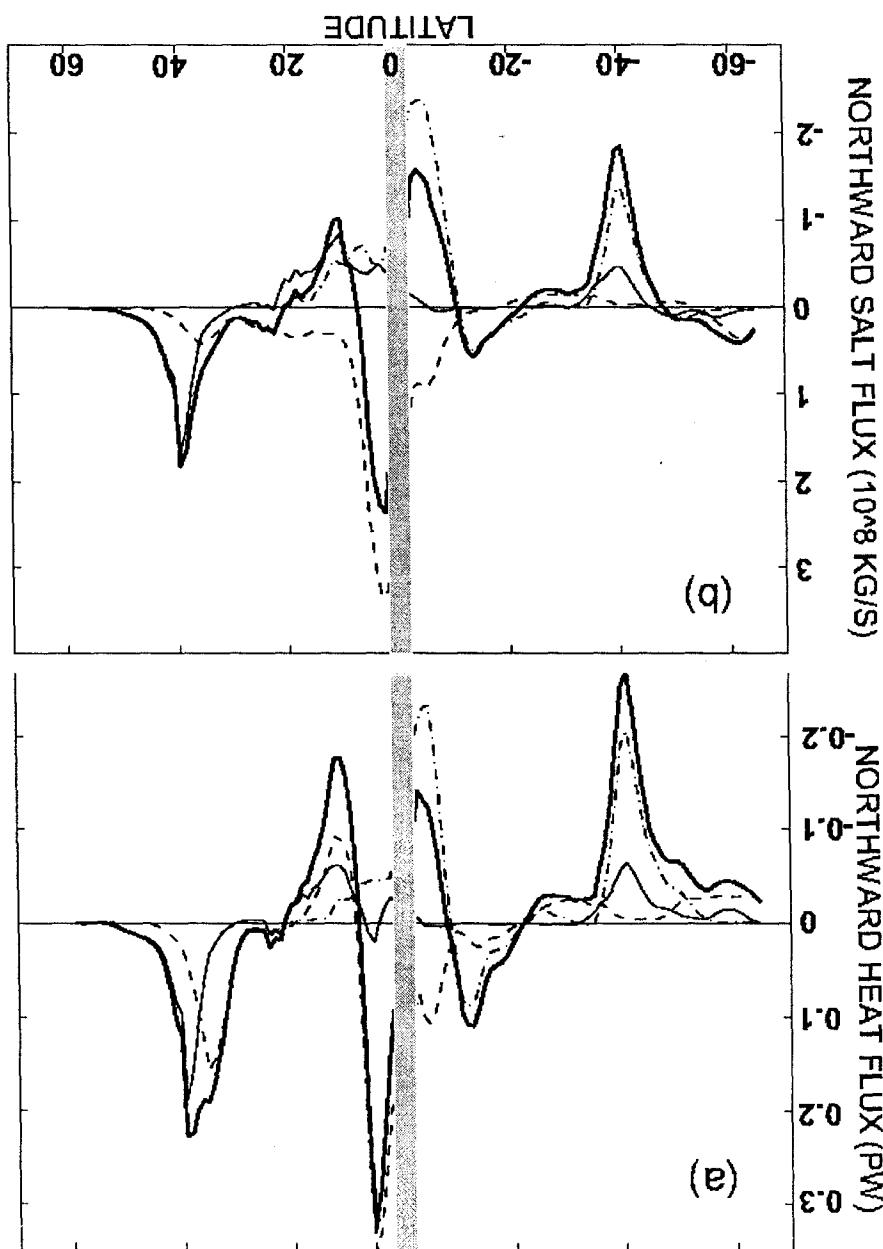
From Smith et al. (2000)



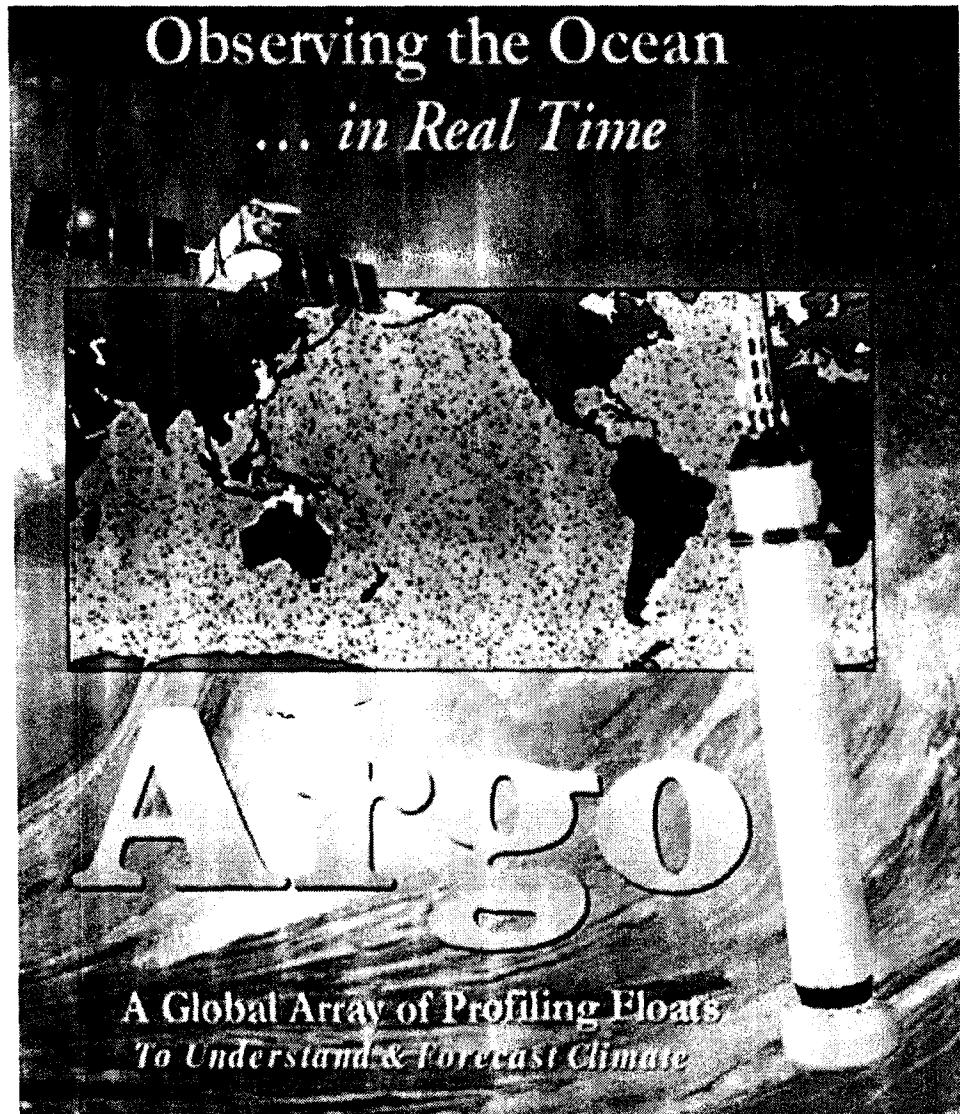
- Observation of current structure in coastal oceans



- Eddy heat and salt transports



Estimating the 3-Dimensional Structure of the Ocean

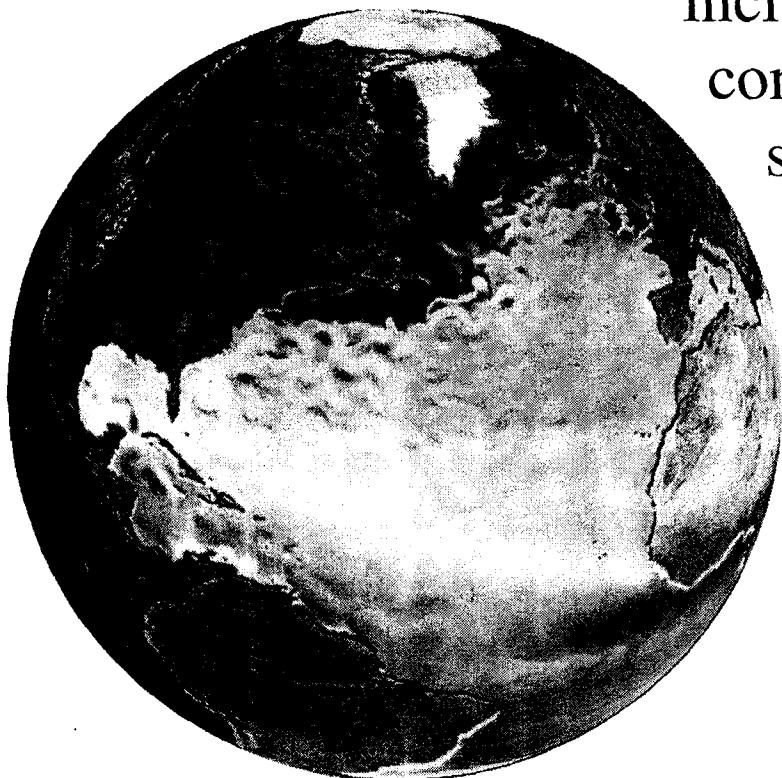


- The ocean is a 3-dimensional fluid whose surface properties are affected by the circulation at depths.
- Satellites cannot observe the deep ocean directly.
- In-situ observations must be made in combination with satellites to observe the 3-dimensional ocean.
ARGO
 - 3000 PROFILING FLOATS
 - 5-YEAR EXPERIMENT,
COORDINATED WITH JASON-1

Estimating the 3-Dimensional Structure of the Ocean

The ocean may never be completely observed. **Mixing on scales of millimeters cannot be observed directly and globally. Yet mixing is essential to ocean's capacity for heat and carbon dioxide.**

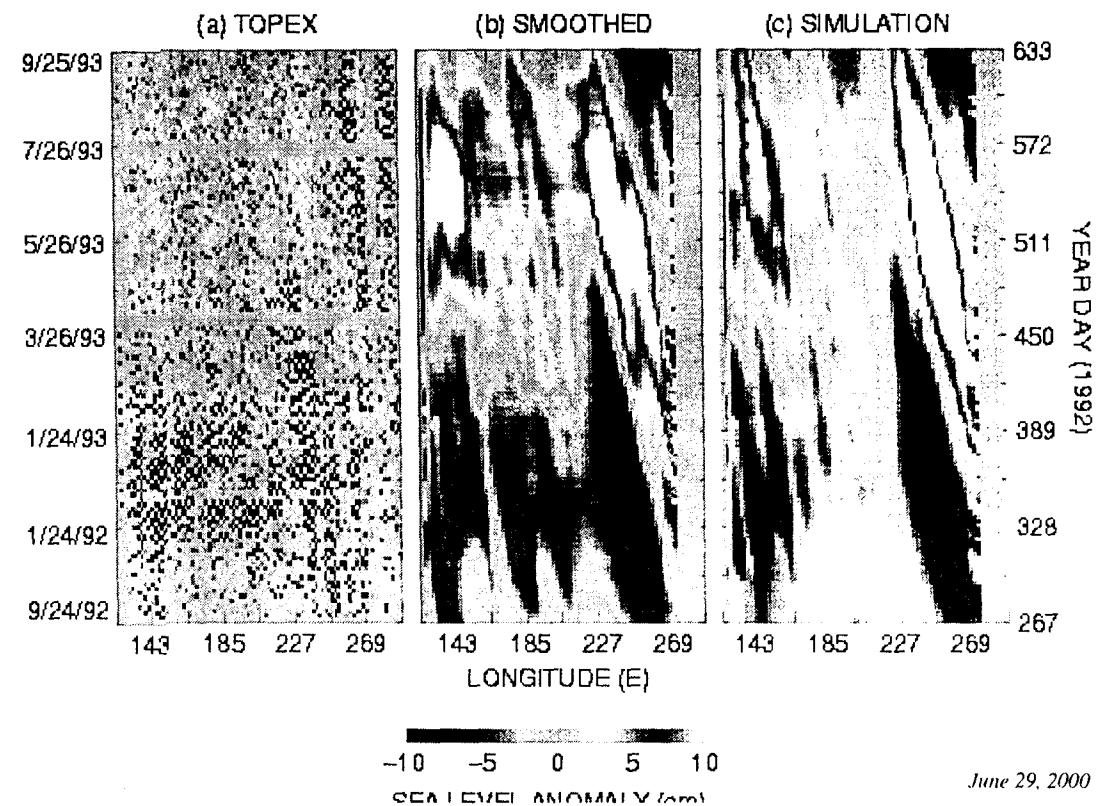
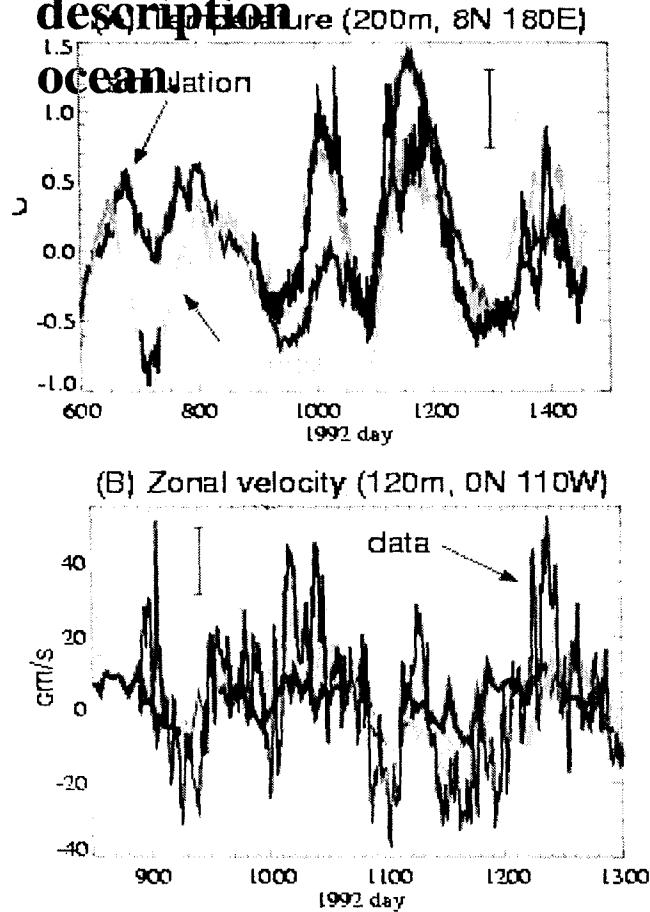
Numerical ocean models simulate the important ocean processes, including mixing. Recent advances in computer technologies have greatly improved such global models.



Computer simulation of the Atlantic Ocean. The color shades represent sea surface temperature. Orange and red are warm temperatures; blue and purple are cold temperatures. The meandering Gulf Stream and its associated eddies are prominent features off the U.S.

Estimating the 3-Dimensional Structure of the Ocean

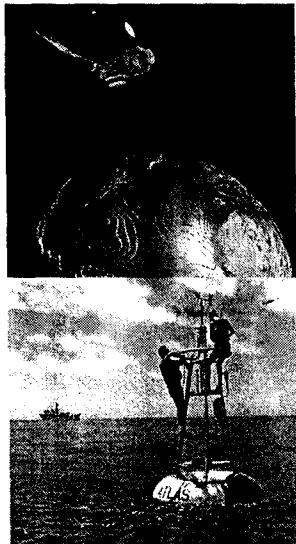
For realistic simulations, numerical models must be driven by accurate wind estimates, and incorporate ocean observations. The combining of observations and models (data assimilation) yields the best of the complete 3-dimensional structure of the ocean.



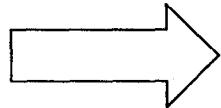
Data Assimilation: The Ultimate Synthesis

Data assimilation is the conduit of information between the observing systems and the user community.

Observing
Systems



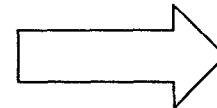
Data



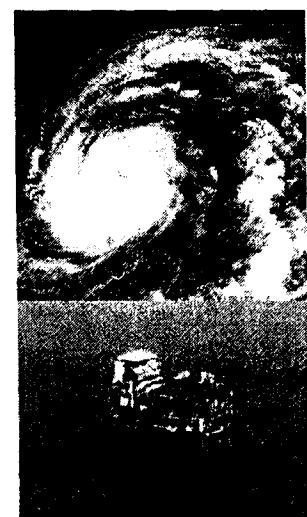
Computer
Ocean
Models



*Synthesis
Products*



User
Community



Data Assimilation: The Ultimate Synthesis

Data assimilation is central to major oceanographic experiments that employ NASA satellite observations.

- **World Ocean Circulation Experiment (WOCE)**

Observations to describe global ocean circulation; 1990~1997. Analysis, Interpretation, Modelling, and Synthesis phase (AIMS); 1997~2005.

- **Climate Variability and Predictability Program (CLIVAR)**

Understand the variability of the climate system with emphasis on quality and continuity of the observations.

- **Global Ocean Data Assimilation Experiment (GODAE)**

Demonstrate feasibility of regular real-time ocean data assimilation and the practical utility of global ocean observations; 2003~2007.

Data Assimilation: The Ultimate Synthesis

NASA contributes to the international global programs with its satellite missions and initiatives in ocean data assimilation. These initiatives are formulated to overcome the challenging computational requirements of data assimilation.

- **Estimating the Circulation and Climate of the Ocean (ECCO)**

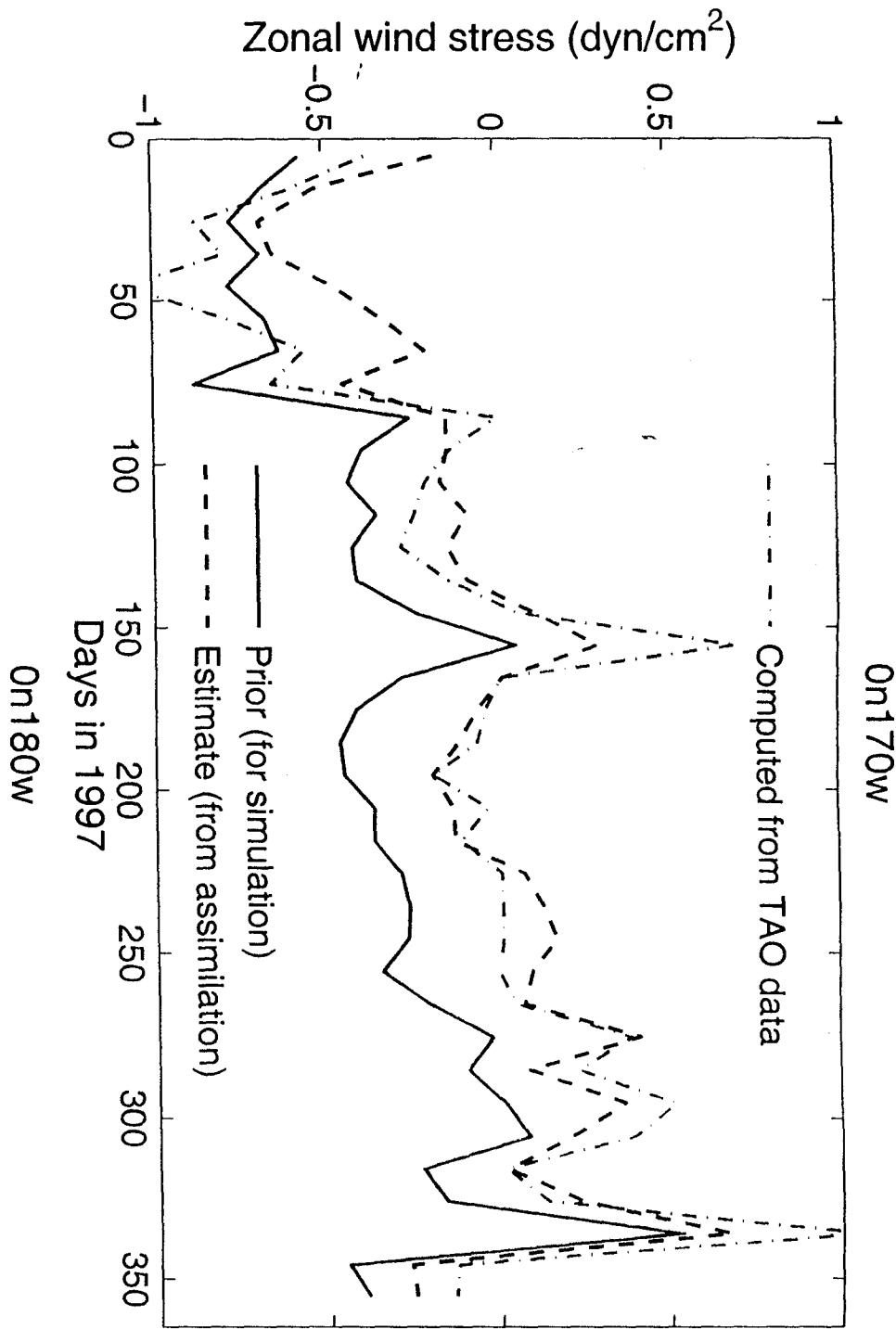
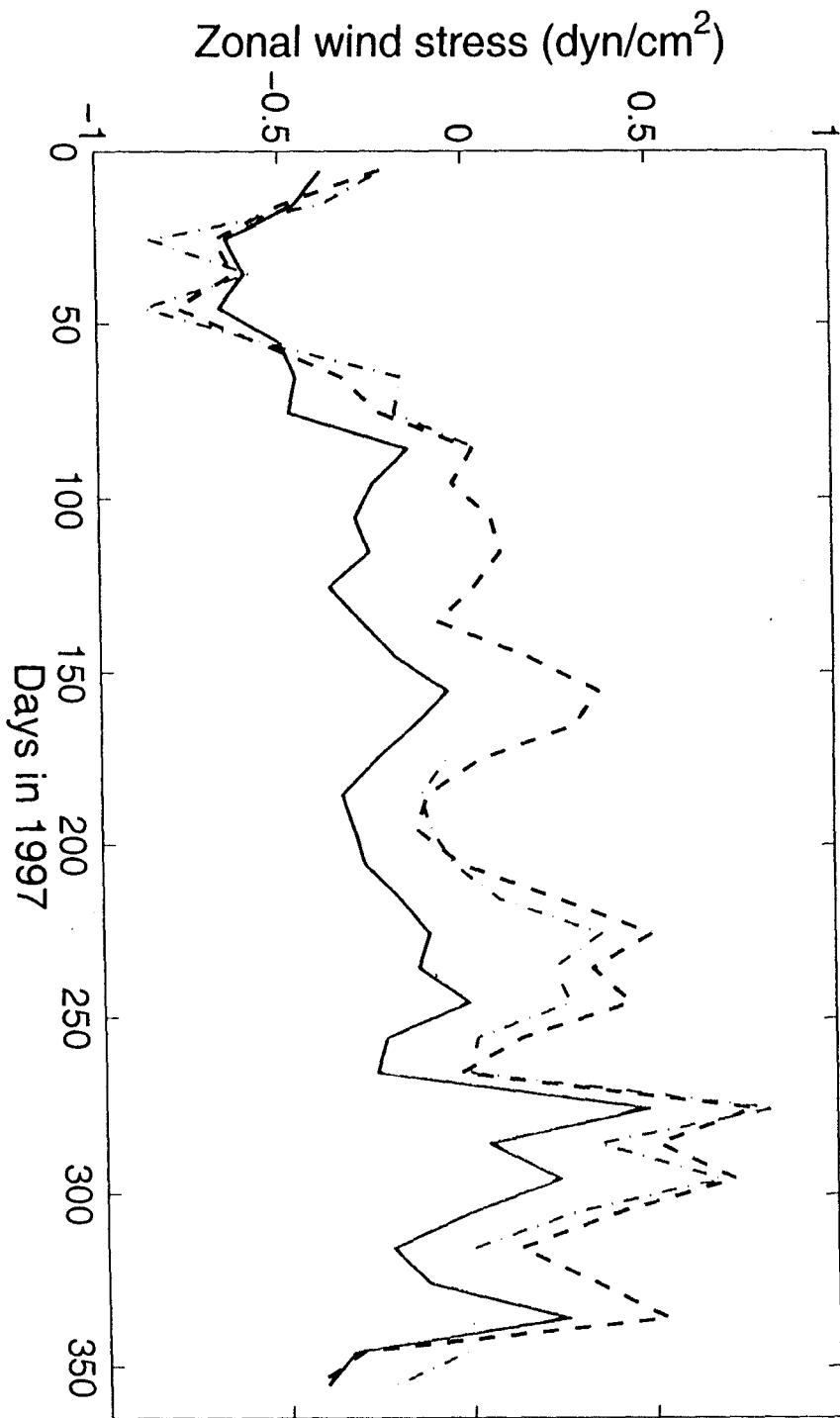
A consortium (JPL, MIT, UCSD) formed under the National Ocean Partnership Program (NOPP); 2000~2004. Aims to advance data assimilation into a practical, quasi-operational tool to monitor and study ocean circulation.

- **NASA Seasonal-to-Interannual Prediction Project (NSIPP)**

Established at Goddard Space Flight Center for experimental predictions of seasonal-to-interannual climate change utilizing satellite data; altimeter, air-sea flux and soil moisture observations.

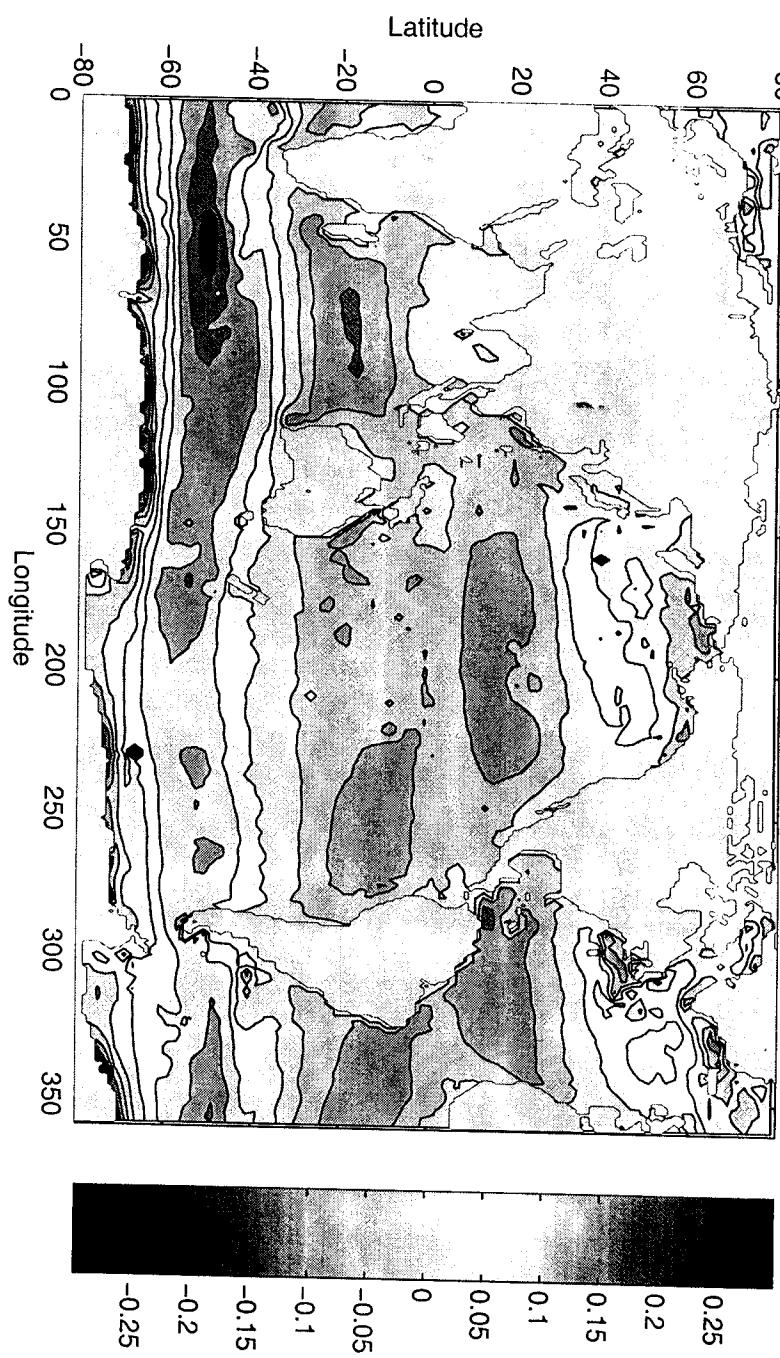
Peak of 1997 El Niño:
sea surface height
relative to normal.



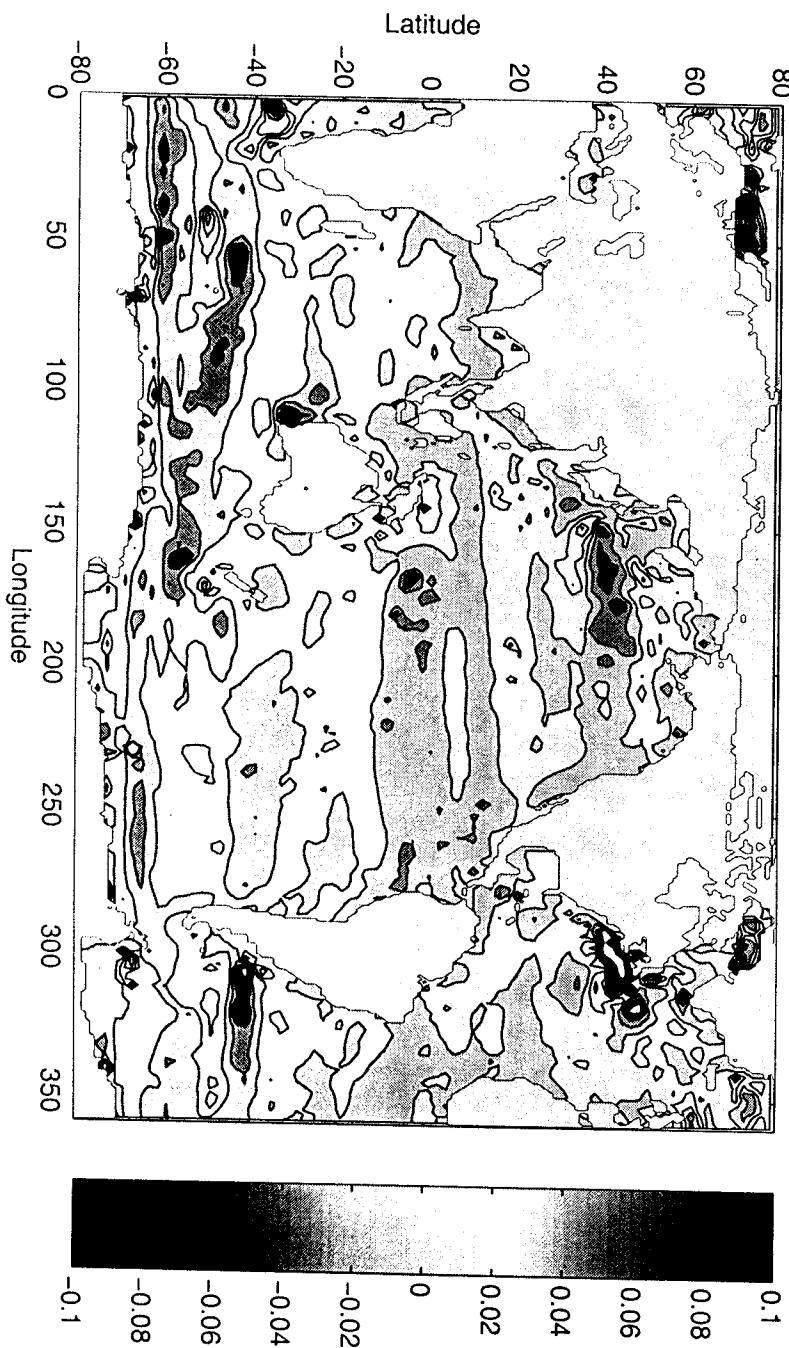


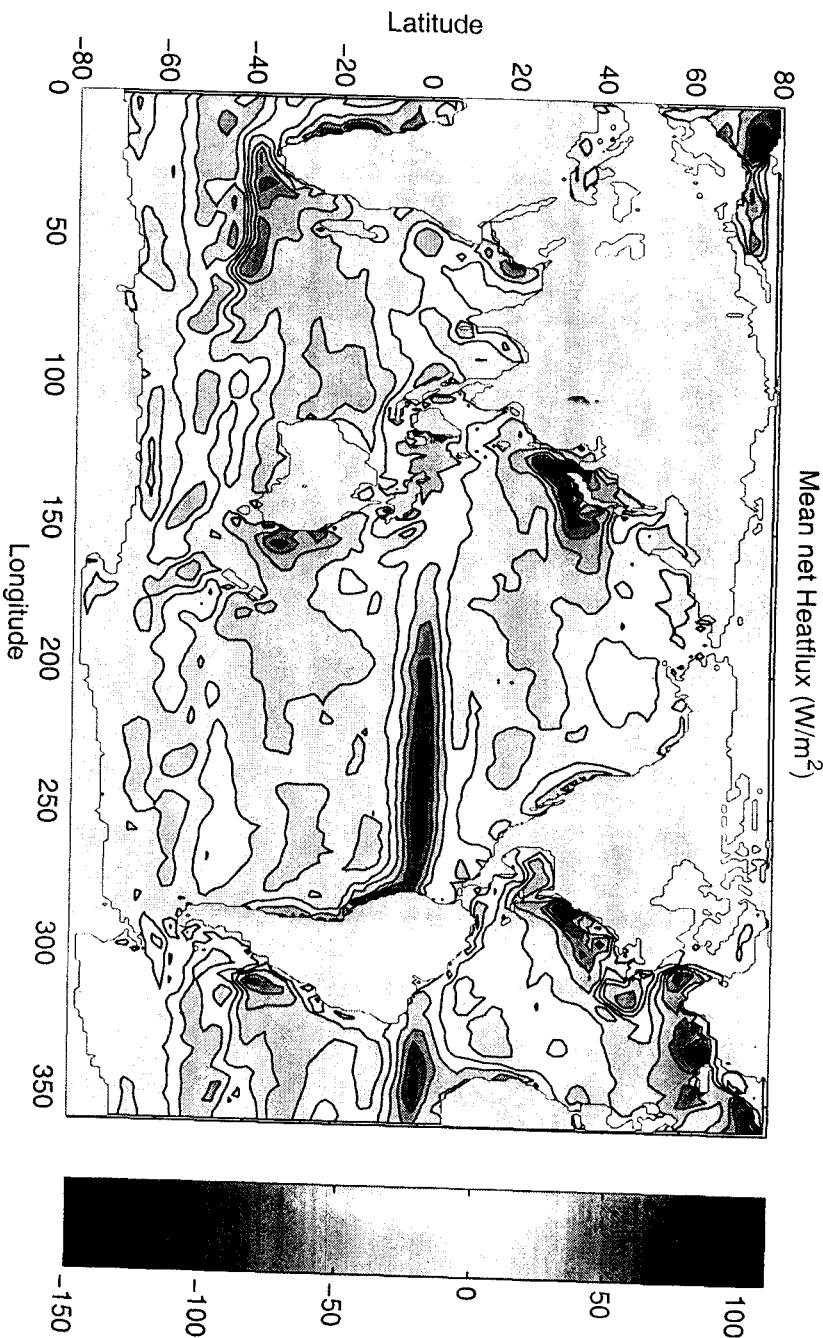
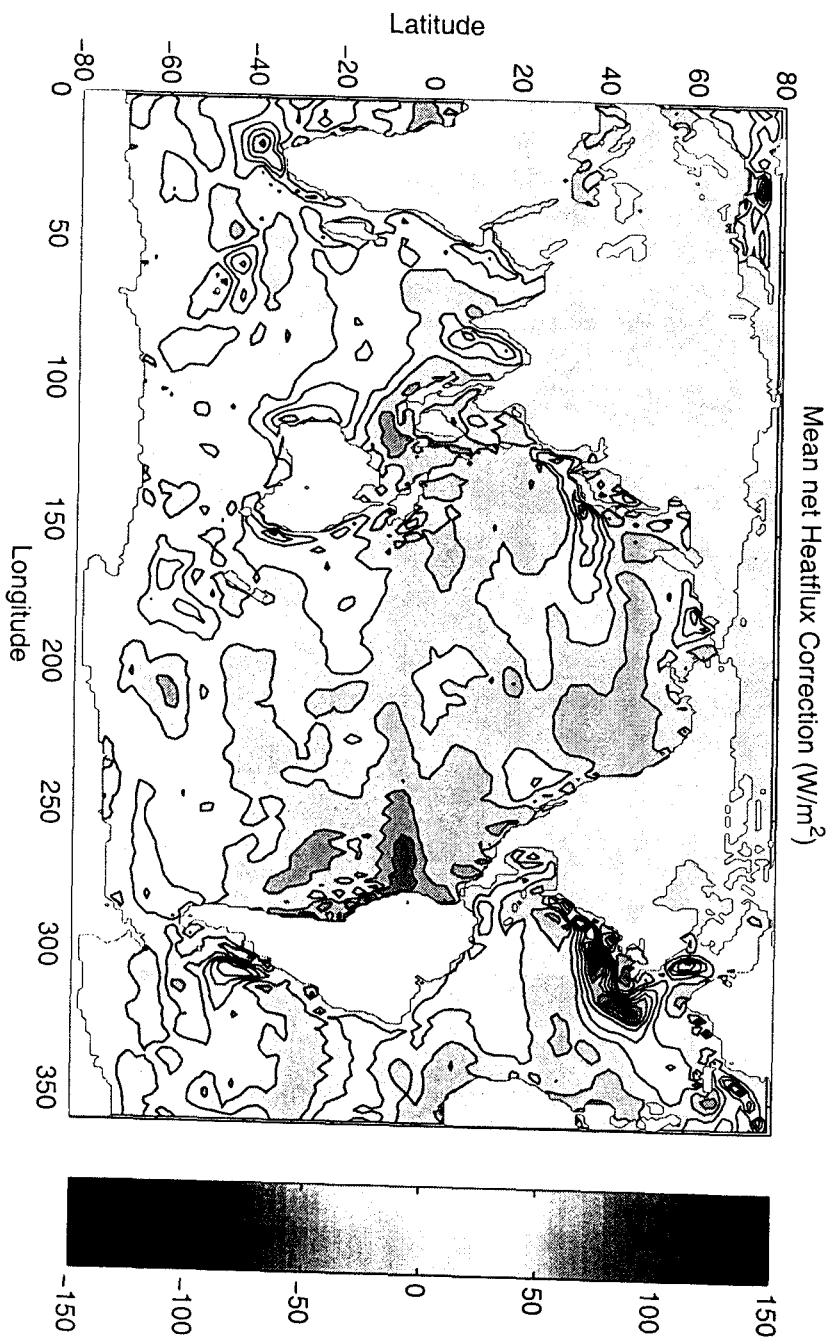
Comparison of prior & estimated zonal wind stress with TAO data

Mean adjusted wind stress component tay_x (N/m^2), iter60



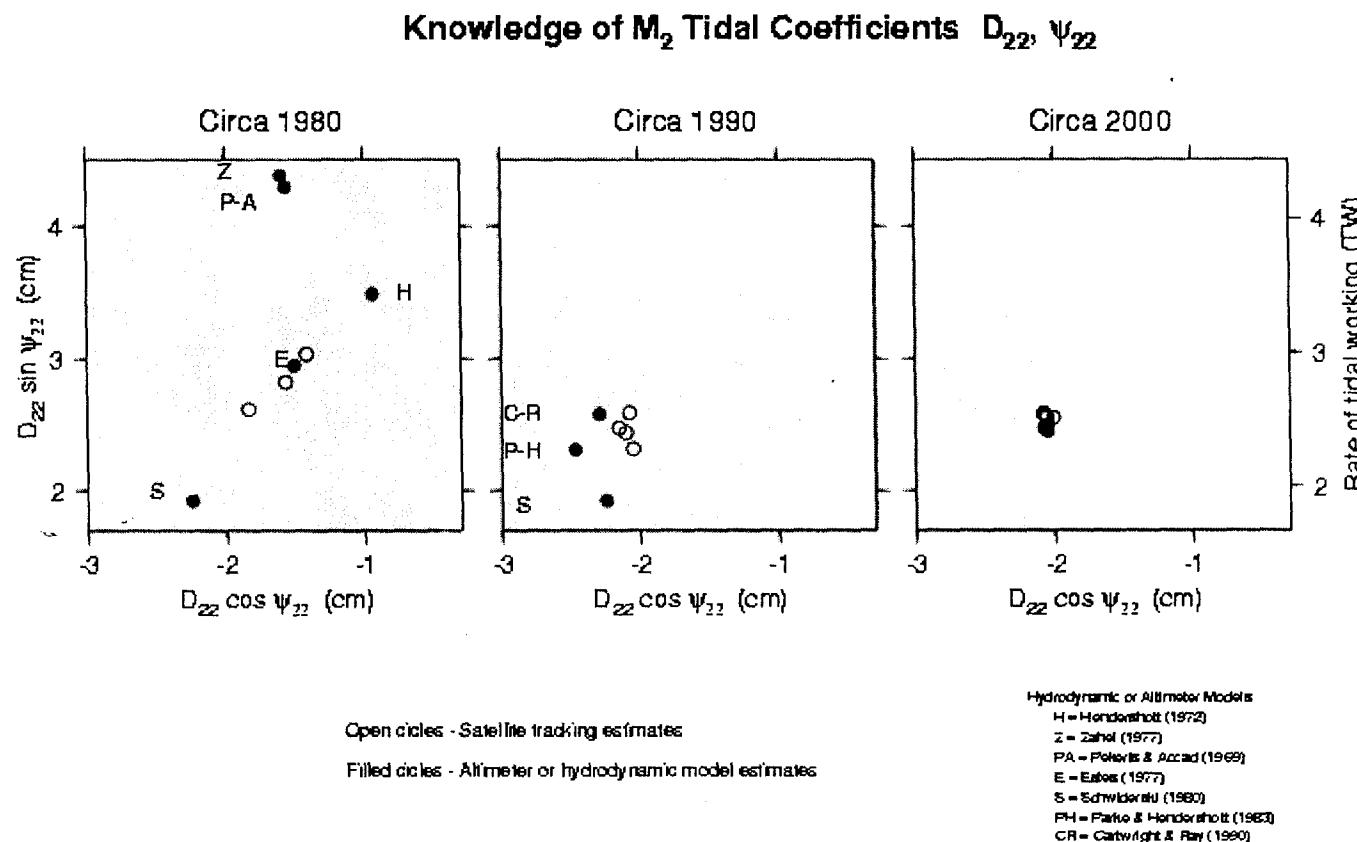
Mean wind stress adjustment tay_x (N/m^2), iter60





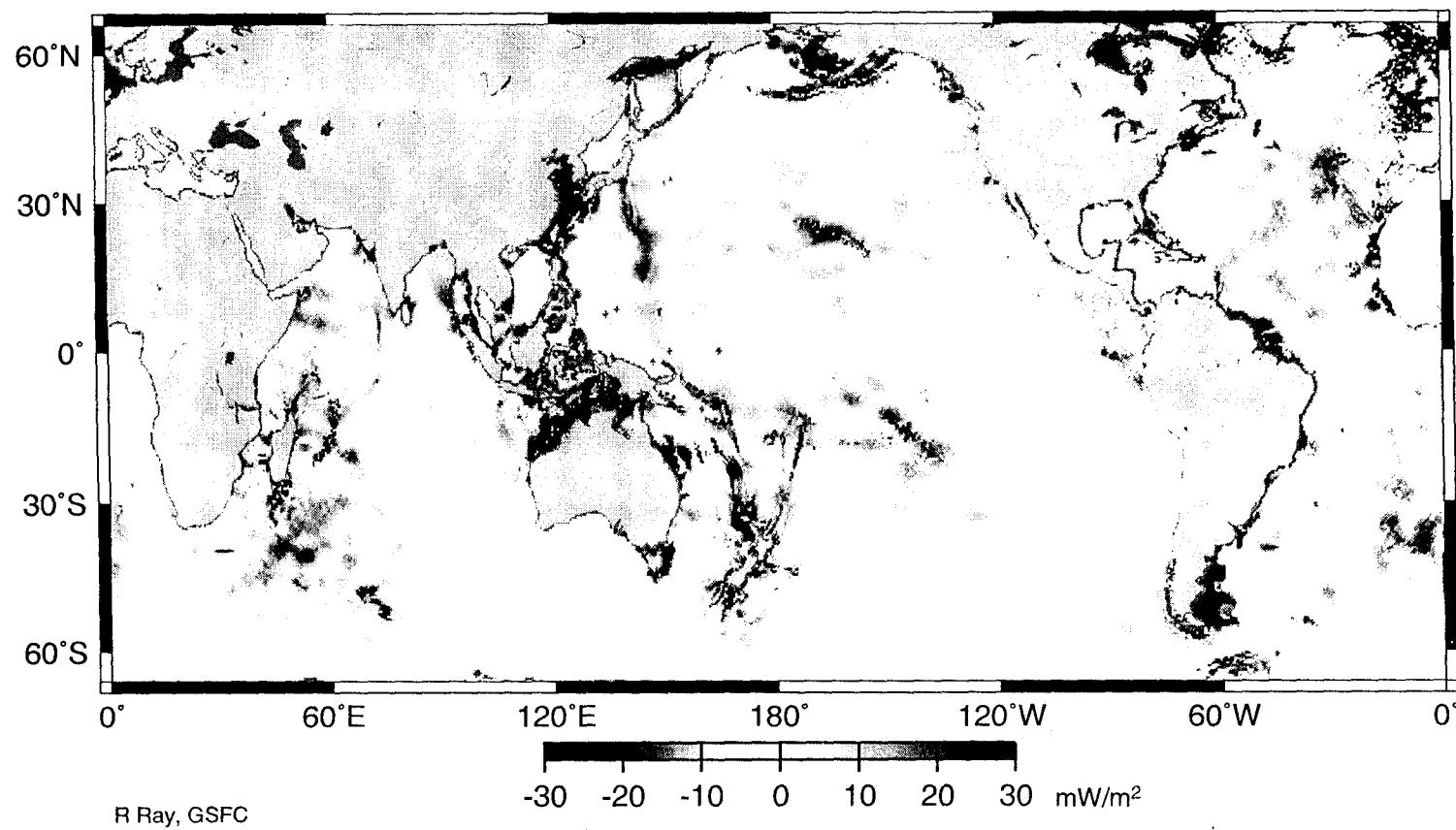
TOPEX/Poseidon Results

Improvement of Global Ocean Tide Models by the TOPEX/Poseidon Mission (from Ray, 2000)

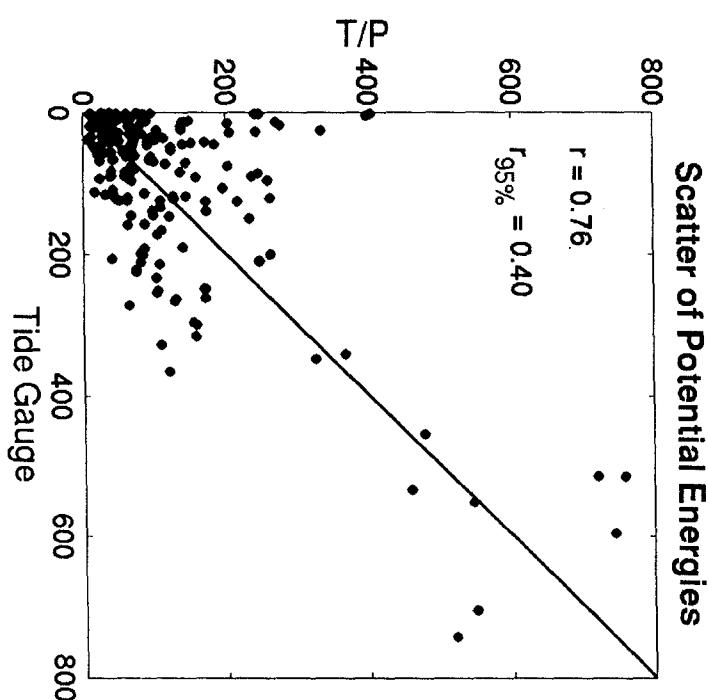
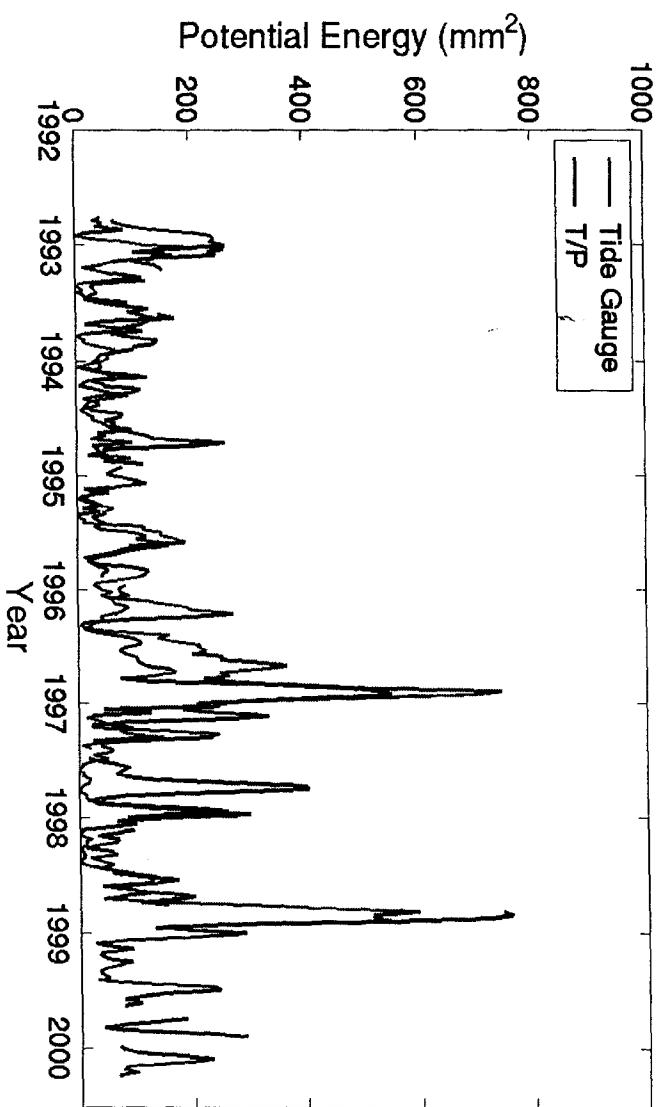


M2 Tidal Energy Dissipation

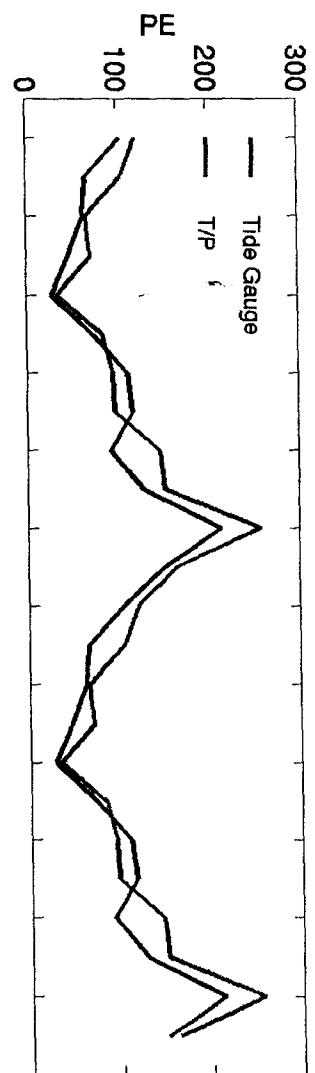
From balance of working and flux divergence



Tarawa Island Intercomparisons



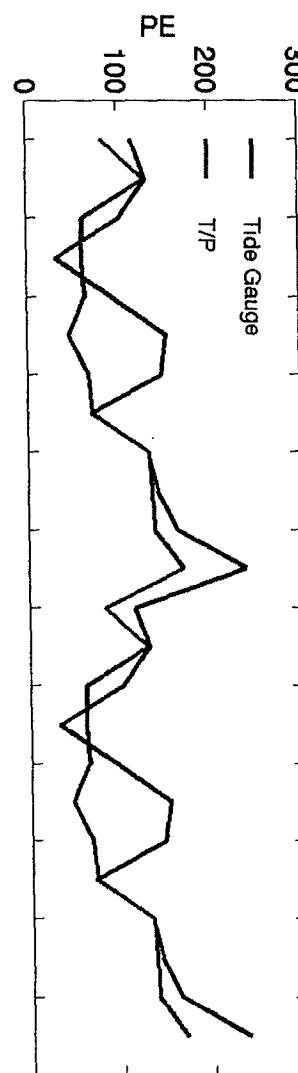
Seasonal cycles at Tarawa Island



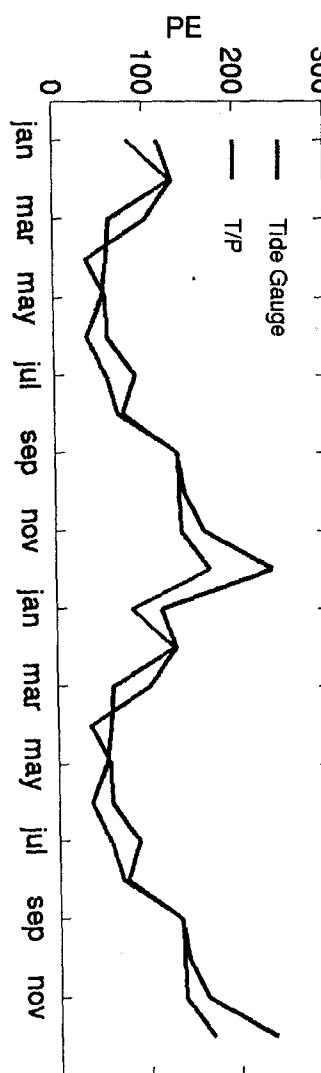
Seasonal cycles at Kanton Island



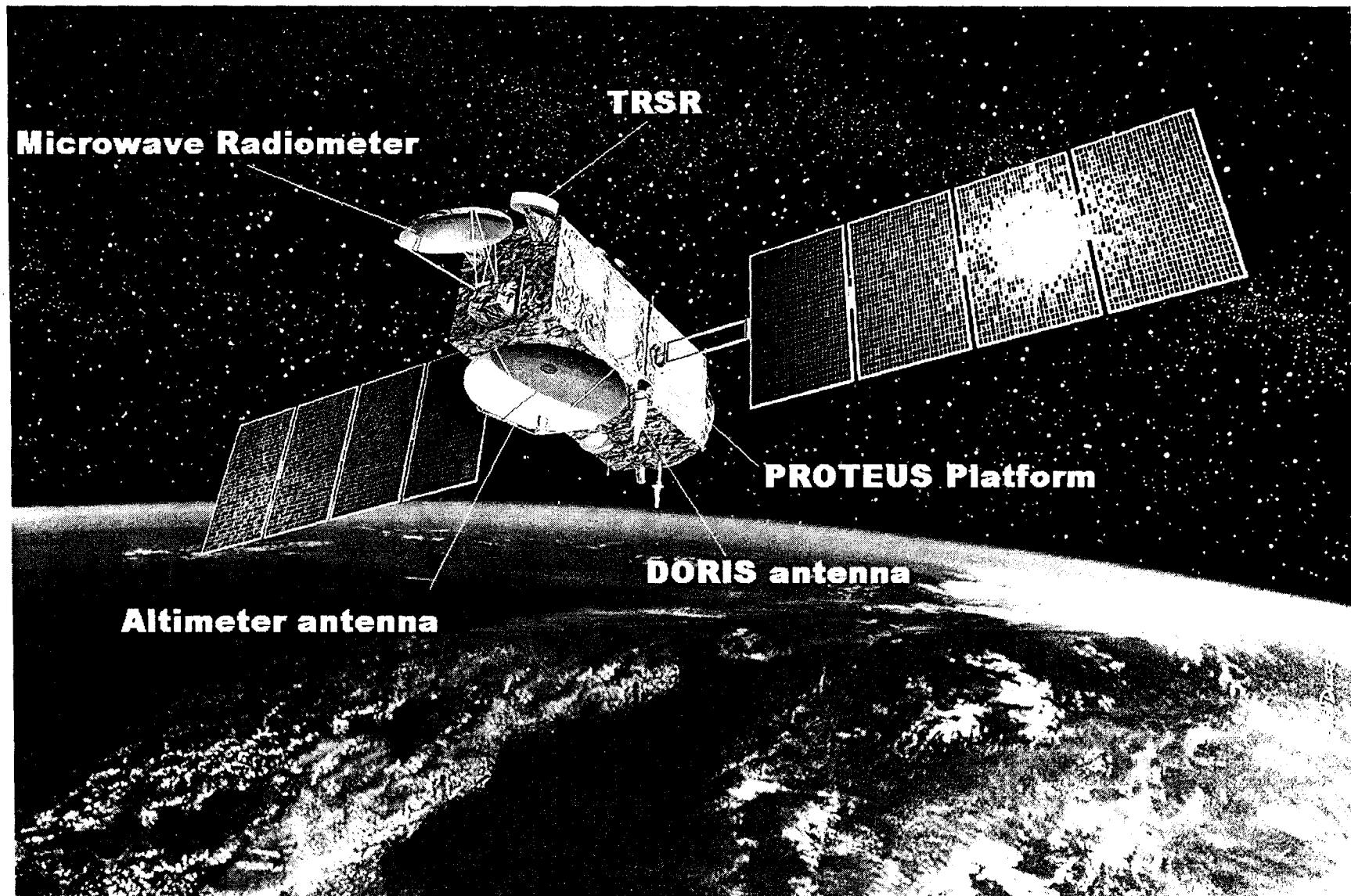
Seasonal cycles at Christmas Island



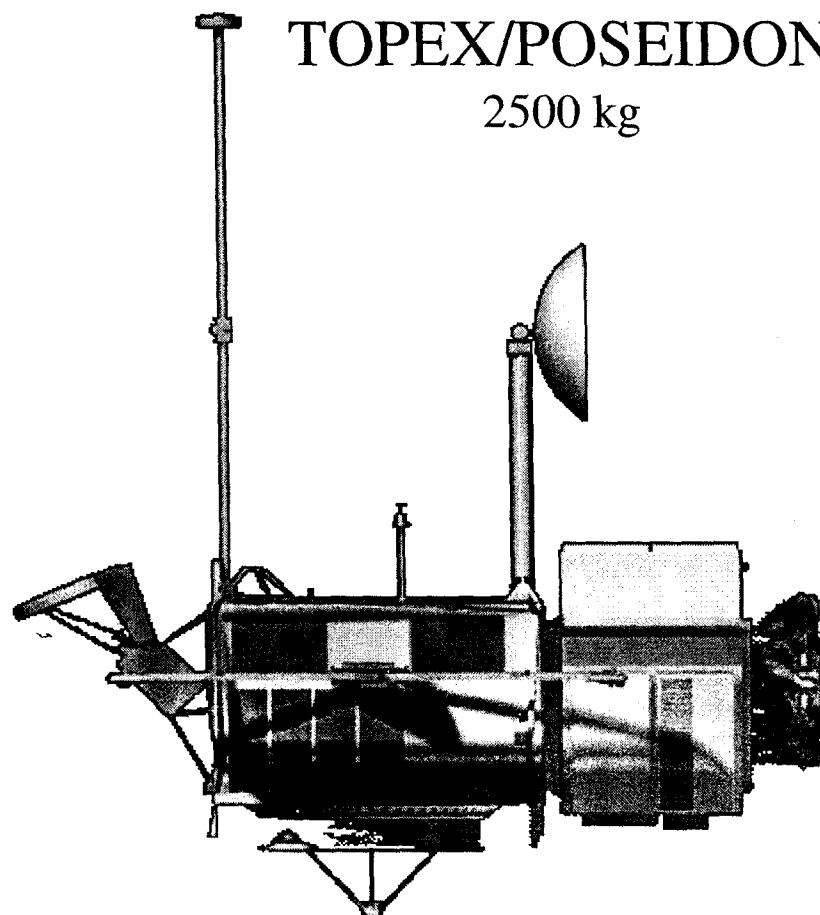
Christmas Island excluding anomalous 1994 event



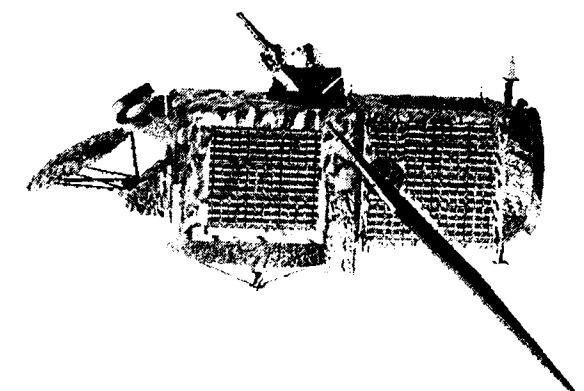
Jason-1 In-Flight Configuration



(1) From TOPEX/Poseidon to JASON



Jason-1
500 kg
Specified performances are the
in-flight T/P performances

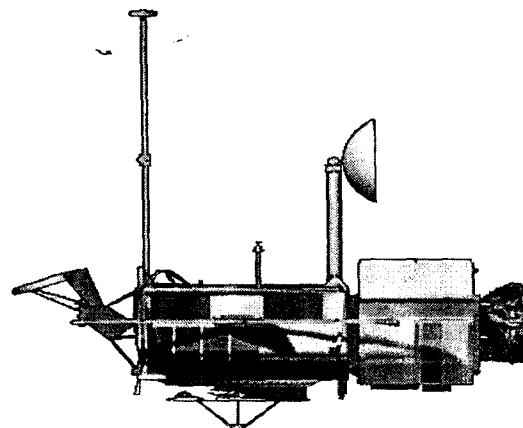


TOPEX/POSEIDON (1992) ; JASON-1 (2001) ; JASON-2 (2005) ; ...

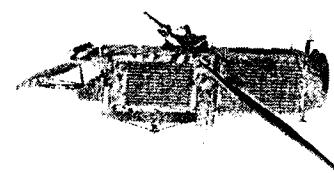
Ocean Topography Missions

- The measurement performance of T/P has met the requirements for quantitative study of the roles of ocean in climate from ENSO to global mean sea level change. This performance is expected to be continued by Jason-1.
- Long-term measurement of ocean topography has been recommended by the science community as an essential element of a global ocean observing system. Jason-2 is pending for approval for continuing the measurement towards 2010, when NPOESS will begin.
- While the radar altimetry technology is being transferred to operational agencies, new technologies for improving measurement performance and cost-effective implementation are being developed: wide swath interferometric altimeter, multiple low-cost altimeters, and GPS reflection receivers.

TOPEX/Poseidon



Jason-1



Jason-2/WSOA

